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THERMAL TESTING OF A SIMULATED ROAD CASK FOR RECENTLY DISCHARGED FUEL

Report No 87-188-K

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ABSTRACT

A full scale experimental study has been carried out to assess the thermal performance of an Irradiated Fuel Road Cask for Recently Discharged (RD) fuel. Tests were conducted to obtain results for shipping irradiated fuel under dry as well as under wet conditions. A simulated cask along with the actual cask internals (Carbon Steel Liner/ Aluminum Basket) and electrically-heated double fuel bundles were employed in carrying out the tests. Temperatures and pressure measurements were made for three power levels and various numbers of bundles in the aluminum basket. The dry cavity tests were carried out without the impact limiter. The water cavity tests were conducted with and without the impact limiter in place. Further dry cavity tests with impact limiter should be conducted as well as water cavity tests with different water levels in the cavity.

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EXECUTIVE SUMMARY

THERMAL TESTING OF A SIMULATED ROAD CASK FOR RECENTLY DISCHARGED FUEL

D. Taralis
Applied Mechanics Section
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This report presents the results of full scale heat transfer tests for the transportation of Recently Discharged (RD) fuel. The objective of the study was to investigate the thermal behaviour of a road cask under dry and wet conditions with and without the impact limiter. An existing simulated cask along with the actual cask internals (Carbon Steel Liner/Aluminum Basket) and electrically-heated double fuel bundles have been utilized in conducting the tests. The results of these tests include:

1. Temperature measurements at various locations throughout the cask for dry and water cavity tests.

2. Pressure versus time/heat input curves for a drained cavity as well as for water cavity tests.

For a dry cavity and 18 fuel bundles the maximum heat input tested was 500 W/Bundle giving a maximum fuel sheath temperature of 512°C. For the water cavity (water at top of aluminum basket) at 900 W/Bundle and without the impact limiter the maximum fuel sheath temperature was 152°C with corresponding cavity pressure of 244 (kPa)g. With the impact limiter in place and for 16 fuel bundles at 700 W/Bundle the maximum fuel sheath temperature was 158°C and the resulting cavity pressure was 379 (kPa)g. Future work should include dry cavity tests with impact limiter and also water cavity tests with various water levels in the cavity.

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THERMAL TESTING OF A SIMULATED ROAD CASK FOR RECENTLY DISCHARGED FUEL

1.0 INTRODUCTION

Ontario Hydro is currently extending the present capabilities of the irradiated fuel transportation system for 10 year cooled fuel (Reference Case) to transporting Recently Discharged (RD) fuel. To accomplish this, the shipping/storage modules in the Reference Case will be replaced by extra shielding and a fuel basket to hold the RD fuel bundles (after at least 8 days of cooling). Other components of the system (road cask, impact limiter and transport trailer) will be unchanged.

The purpose of this study was to establish an optimum bundle power (decay heat) under dry and wet cavity conditions by making temperature and pressure measurements on a full scale experimental apparatus. The tests conducted involved the simulation of the conditions for the following phases of operation of the cask:

i) Dry Cavity
ii) Reflood/Water Cavity
iii) Dry Unloading

This report describes the various components of the test apparatus and the instrumentation used. It further describes briefly the above phases of operation of the cask, presents and discusses the results of the tests and states the main conclusions and recommendations of this work.

2.0 TEST APPARATUS

This section describes the experimental apparatus that has been employed to study the thermal behaviour of a simulated road cask for the transportation of RD fuel.

2.1 Simulated Cask

Figure 1 shows a schematic diagram of the simulated cask. It is made of carbon steel and consists of the main body and the lid bolted together using a rubber gasket for sealing the cavity. The lid has two openings for passing through the heaters and the thermocouples. A drain has been provided near the bottom at the middle of one of the sides of the cask. Two additional steel plates were firmly attached to the walls of the cavity (opposite each other) so that the resulting cavity size is equal to that of the road cask. The vessel has been designed according to the ASME pressure vessel code section VIII, Division 1 for 700 (kPa)g and 150°C.

2.2 Carbon Steel Liner and Aluminum Basket

This part of the apparatus is the actual cask internals. Figure 2 shows an isometric view of the carbon steel liner and the aluminum basket. The liner which encases the basket is used for providing extra shielding to the lower portion of the cask. The aluminum basket is used for storing the RD fuel bundles as well as for providing extra shielding to the upper portion of the cask. The basket consists of nine longitudinal holes bored in a square pattern and all are sleeved with stainless steel sheet. A maximum of 18 fuel bundles (2 bundles per hole) can be accommodated in the aluminum basket.

2.3 Simulated Fuel Bundles

The geometry of the simulated fuel bundles is essentially identical to the Pickering fuel bundles (28 elements). For convenience the length of the simulated bundles was made equal to the length of two fuel bundles since there will be two bundles per basket hole. To model the maximum capacity of the aluminum basket a total of 9 double fuel bundles were built.

The heat input to the simulated bundles was accomplished using Chromalox custom made heaters. Since the program involved dry (air) tests as well as water tests, it was necessary to design heaters that would be suitable for operating at high temperatures in dry environment and also under water at much lower temperatures. To meet these requirements, heaters with very long cold sections were built so that their terminals were outside the cask cavity. This eliminated the need of hermetically sealing the heater terminals which would be required for under water operation. Figure 3 shows the type of heaters used along with the design data and Figure 4 shows the electrically simulated double fuel bundle.

2.4 Simulated Impact Limiter

Figure 5 shows the simulated impact limiter placed over the lid of the simulated cask. The impact limiter was made of fiberglass insulation of sufficient thickness for approximating ideal insulating conditions. The fiberglass insulation was protected by encasing it in steel sheet metal. This type of fiberglass insulation is suitable for applications up to 510°C which is well above the present requirements.

2.5 Assembly of Apparatus

The simulated fuel bundles were loaded into the aluminum basket and the steel liner was placed into the simulated cask as shown in Figure 6. Next the aluminum basket was placed into the steel liner and the cask lid was bolted to the cask (see Figure 7). The thermocouple leads and heater terminals were passed through the two lid openings and individually sealed using gland connectors as shown in Figure 8.

3.0 TEST INSTRUMENTATION

The instrumentation used in carrying out the tests involved a number of thermocouples, a pressure transducer, a water flow meter, a power meter and a data acquisition system. These items are briefly described below.

3.1 Thermocouples

Thirty-three stainless steel sheath thermocouples type k (Chromel-Alumel) were selected on the basis of the following requirements:

i) To operate in dry as well as in water environments.
ii) To provide good sealing between cask cavity and outside environment.
iii) To measure temperatures in the range of 0°C to 1000°C.

The location of these T/C's and the numbering scheme used are shown in Figure 9.

3.2 Pressure Transducer

The cavity pressure was measured using both an electronic pressure transducer and a pressure gauge. The transducer covers the pressure range from 0 to 750 (kPa)g although it can accurately sense negative pressures (vacuum). The output voltage of the transducer was automatically converted to pressure units by the data acquisition system described in Section 3.5. The transducer was installed at one of the lid openings.

3.3 Flow Meter

This meter consists of a rotating vane whose rotational speed is proportional to the rate of water flow. The output of the meter was in terms of the number of pulses which can be counted using a frequency counter. For a given valve opening the water flowing through the meter was measured over a time interval and the corresponding number of pulses was noted. Carrying out this simple test for various valve openings one obtains the graph shown in Figure 10. The flow meter was installed at the cask drain through which water was admitted into the cask cavity during the cavity reflood and water cavity tests.

3.4 Power Supply

The power input to the electric heaters was supplied from a single phase power supply of 208 VAC. A five stack variable transformer with voltage output 0 to

230 VAC was used for setting the desired power level to the model. The maximum capacity of the variac was in the order of 20 kW. All heaters were connected in parallel and protected by circuit breakers. Power measurements were made using a portable single phase YEW (Yokogawa Electric Works) wattmeter. Since the maximum current required in the tests was higher than the meter capacity a current transformer with ratio 1 to 20 was used.

3.5 Data Acquisition System

Temperature and pressure measurements were made using the AUTO DATA 10 system. This system has the capability of accepting a larger number of inputs and allows each channel to be programmed to a different type of thermocouple. Up to seven types of thermocouples including the most common types used are available on this system. The temperatures at the instrumented locations were monitored at regular time intervals to determine the steady state conditions. Cavity pressure and temperature readings were taken and permanently recorded on paper.

4.0 TEST RESULTS

This section presents the results of the tests conducted for simulating the three phases of operation of the road cask for the transportation of RD fuel. Table 1 lists the various types of tests that have been carried out.

4.1 Dry Cavity Tests

The objective of these tests was to study the thermal performance of the cask/shield/basket arrangement under dry conditions (cavity filled with air) by investigating different bundle powers and various numbers of bundles in the aluminum basket.
In total 10 dry cavity tests without the impact limiter were conducted and the temperature measurements made are shown in Figures 11 through 20. The results for 4 bundles in the aluminum basket (2 bundles/hole) at three power levels (200, 430 and 500 W/Bundle) are shown in Figures 11, 12 and 13. For 8 and 18 bundles the results are shown in Figures 14 to 19.

To study the effect of bundle arrangement on the fuel temperature one additional test for 8 bundles at 500 W/Bundle was carried out. The results obtained are shown in Figure 20. A comparison of this figure with Figure 16 reveals that the temperatures shown in Figure 20 are slightly lower. Therefore, when shipping fuel at less than full capacity, the bundles should be spaced as far apart as possible.

In general, all of the results of the dry tests exhibit the same basic trends. The cask inner surface temperatures decrease with height as expected since the heat transfer from the bottom of the cask is very small due to the insulated conditions. The temperature drop across the cask wall as indicated by T/C's 25 and 32 (see Figure 9) is not as low as one would expect for a homogeneous steel wall. This is the result of the contact resistance between the steel plates that were attached to the cask inner surfaces to achieve the actual cavity size.

The cavity pressure at the end of the dry cavity tests was approximately equal to the atmospheric pressure. Under ideally sealed conditions the cavity pressure would have been slightly above atmospheric.

4.2 Cavity Reflood/Water Cavity Tests

These tests dealt with the simulation of the unloading phase of operation of the cask at the receiving end. It involved flooding the hot dry cavity with water while the electric heaters continued to generate heat. Water was fed into the cavity from the drain while the vent was left open (in the actual case the vent will be installed with a filter). The objective of these tests was to provide an insight into the cooling process of the fuel cavity and cavity pressure build-up as a result of the evaporating water. In addition further tests were carried out at several power levels with water in the cavity up to the top of the aluminum basket with and without the impact limiter in place.

Figure 21 shows the cavity pressure as a function of time after admitting water into the hot cavity (initial temperature conditions shown in Figure 22) at the rate of approximately 40 liters/minute. As this figure shows, during the first 20 seconds or so the pressure was increasing gradually and then it began to rise at a very high rate reaching 355 (kPa)g within 75 seconds. To avoid taking a risk of exceeding the design limits (pressure/ temperature) the relief valve was opened and the pressure immediately began to fall as can be observed in the same figure. The temperature readings at the instant when the relief valve was opened are shown in Figure 23. This figure shows that the cask wall and cask lid temperatures are higher than they were before admitting water into the cavity. Although some temperatures decreased as indicated by T/C's 19 (top of the aluminum basket) and 20 (side of steel liner) the aluminum basket hole temperatures, however, remained practically the same.

The water cavity tests involved filling the cavity with water to the top of the aluminum basket. Figures 24 through 29 show the steady state temperatures and pressures for two bundle arrangements and three power levels (200, 500 and 900 W/Bundle) without the impact limiter in place. The temperature and pressure results with the impact limiter are shown in Figures 30 to 38. These results correspond to three bundle arrangements and three heat inputs (200, 500 and 700 W/Bundle). It should be noted that the temperatures corresponding to the water cavity tests are fairly uniform unlike the temperatures of the dry cavity tests.

Figure 39 presents the cavity pressure as a function of the heat input to the model for various bundle arrangements with and without the impact limiter. As this figure illustrates it is possible even at high bundle powers for the cavity pressure to be below atmospheric when the number of bundles in the aluminum basket is small. The reason for this is explained below.

4.3 Dry Unloading Tests

The dry unloading tests were conducted to establish the pressure behaviour of the cask due to residual water vapour. Following the reflood tests and with

the heaters still on (550 W/Bundle) the cavity was drained and subsequently the drain valve was closed.

Figure 40 shows the cavity pressure as a function of time. It is interesting to note that the pressure is negative (below atmospheric) and not positive as one might have expected. When the cavity is filled with water the cask walls are at a higher temperature in comparison to the walls of the dry cavity. Once the cavity is drained the cask walls get cooler while the aluminum basket temperatures begin to rise. Any water vapour in the cavity condenses on the walls of the cask, thus creating a vacuum. Figure 41 shows the temperatures measurements at the end of the dry unloading test. Comparison of this figure with Figure 19 reveals that the temperatures obtained from the dry unloading tests are lower. Although the test conditions of Figure 19 and 41 are not exactly the same (500 vs 550 W/Bundle) it appears, however, that the heat dissipation characteristics of a cask containing residual amounts of water are better than those of a completely dry cavity.

4.4 Maximum Fuel Sheath Temperature

In determining the maximum fuel sheath temperature for the dry cavity and water cavity tests the experimental results of reference/1/ have been employed. These results which were obtained from dry (air) and water tests are shown in Figure 42 in terms of the temperature difference between the maximum fuel sheath temperature and the average module tube temperature as a function of the heat input to an electrically-heated bundle. Using the average temperature of the hottest aluminum basket hole (present results) and the temperature difference of Figure 42 one obtains the graphs shown in Figures 43 through 45 for the dry cavity tests and Figure 46 through 48 for the water cavity tests. As can be seen from these figures the temperatures for the dry cavity are quite high in comparison to the water cavity. This is of course due to the poor heat transfer properties of air. For example with 18 bundles in the aluminum basket at 500 W/Bundle and without the impact limiter, the maximum fuel sheath temperature for the dry cavity is 512°C (see Figure 43) while for the water cavity it is only 113°C (see Figure 46). Since it is useful to have the maximum fuel sheath temperature results in terms of the number of bundles in the aluminum basket or in terms of the total cask heat load the results of Figure 43 have been plotted in Figures 44 and 45 and the results of Figure 46 have been plotted in Figure 47 and 48. It should be noted that the curve for 13 bundles in Figure 46 or in Figure 48 has been obtained by interpolation since no test with 13 bundles in the aluminum basket has been conducted.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the following conclusions and recommendations can be made:

a) For a dry cavity with 18 fuel bundles in the aluminum basket (maximum capacity) the maximum decay heat level tested was 500 W/Bundle giving a maximum fuel sheath temperature of 512°C. The corresponding cavity pressure at the end of the test was approximately equal to the atmospheric pressure.

b) For the water cavity (water level at the top of the aluminum basket) containing 18 fuel bundles and without the impact limiter a maximum heat input of 900 W/Bundle was tested. The corresponding maximum fuel sheath temperature was 152°C at a cavity pressure of 244 (kPa)g. With the impact limiter in place and 16 fuel bundles active at a heat input of 700 W/Bundle the maximum fuel sheath temperature was 158°C and the cavity pressure was 379 (kPa)g.

c) Flooding the hot dry cavity with water at a rate of 40 liters per minute while all 18 fuel bundles continue to generate heat (500 W/Bundle) raises the cavity pressure from 0 to 355 (kPa)g within 75 seconds, while fuel temperatures remain essentially the same (compare Figure 22 and 23). Additional water in the cavity could have produced cavity pressures in excess of 700 (kPa)g (maximum design pressure).

d) During the dry unloading tests (with 18 fuel bundles active at 550 W/Bundle) the cavity pressure falls below atmospheric reaching a minimum value of -24 (kPa)g and rises just above atmospheric pressure when steady state conditions are reached (see Figure 40).

e) Further dry cavity tests with an impact limiter as well as additional water cavity tests with different water levels in the cavity should be carried out.

ACKNOWLEDGEMENTS

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D. Taralis

D. Taralis
Engineer
Applied Mechanics Section

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1. Taralis, D. "Thermal Testing of Irradiated Fuel Storage Module Tubes in Water and Air", Ontario Hydro Research Division Report No 80-254-K, July 1980.

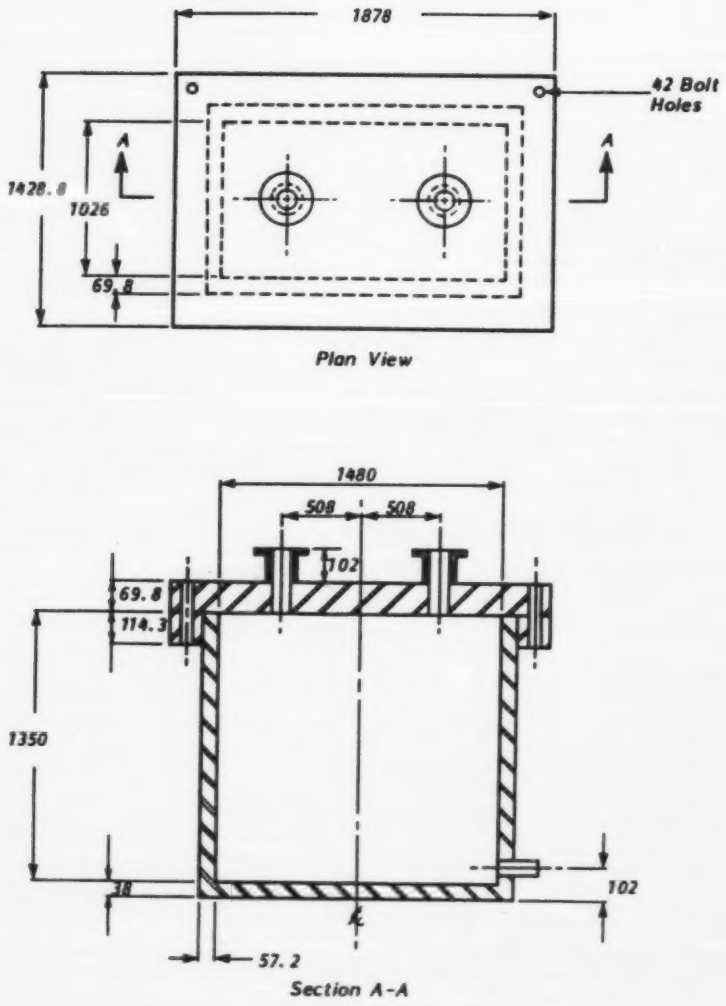
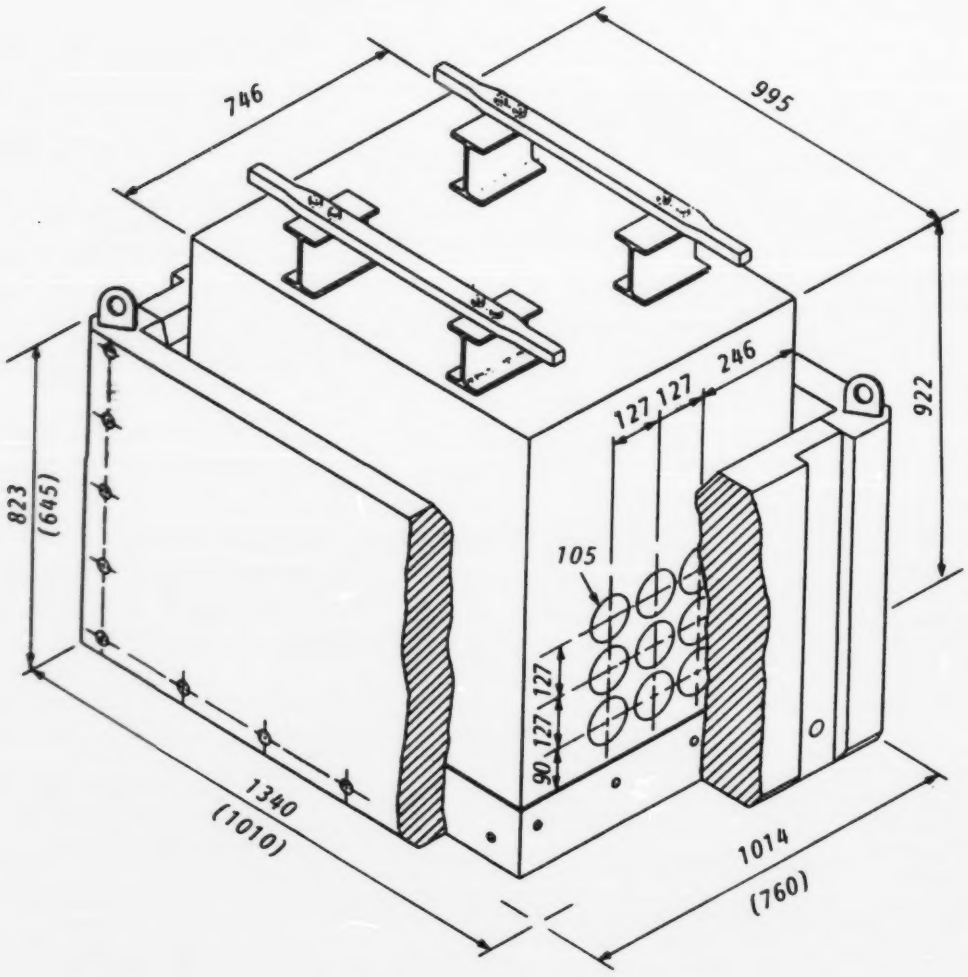


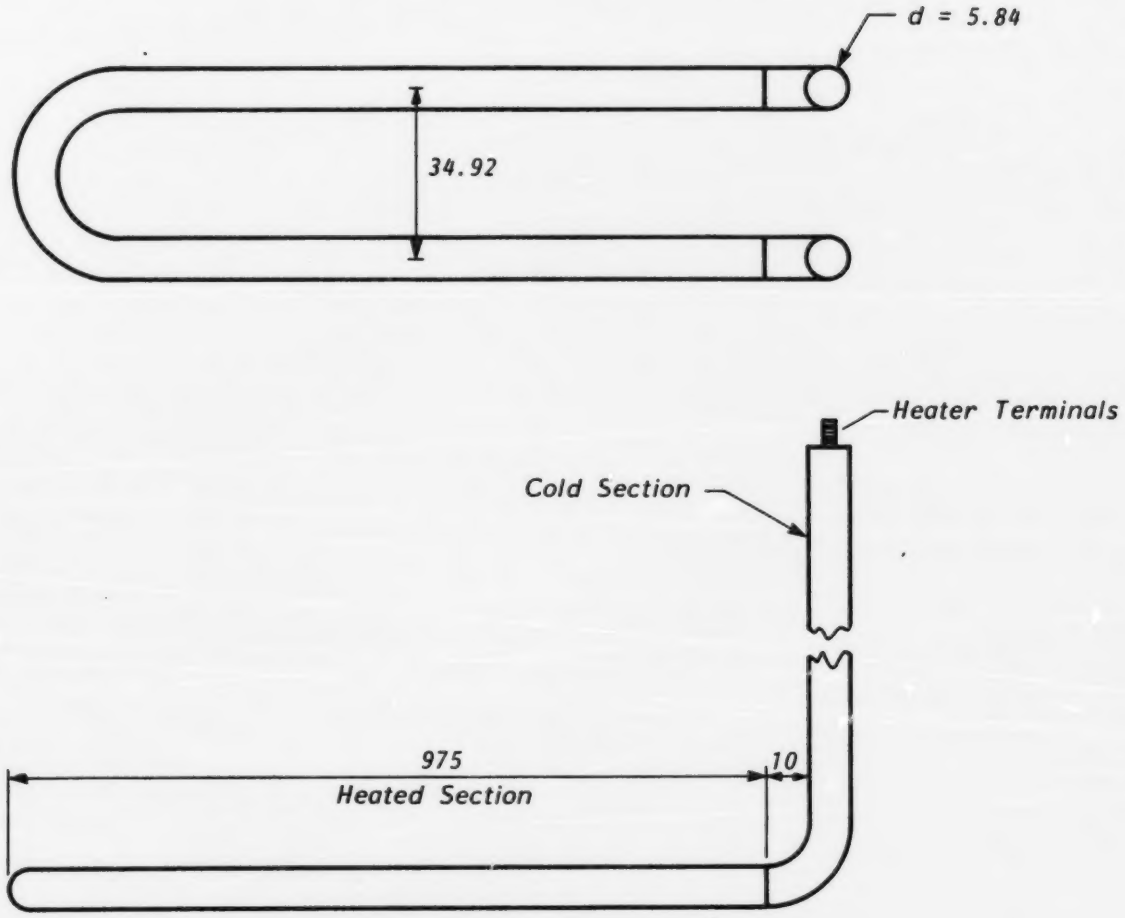
FIGURE 1
SCHEMATIC DIAGRAM OF THE SIMULATED CASK



( ) Brackets demote inner surface dimensions

All dimensions in mm

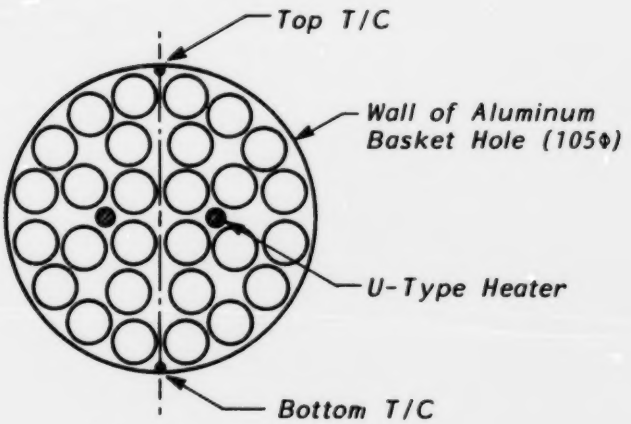
FIGURE 2
CARBON STEEL LINER AND ALUMINUM BASKET
(ACTUAL CASK INTERNALS)



Rared at 2000 W at 208 VAC 1ϕ
Electrical Resistance = 24 Ω
Maximum Heater Surface Temperature = 800°C

All Dimensions in mm

FIGURE 3
U-TYPE ELECTRIC HEATER WITH LONG COLD SECTIONS



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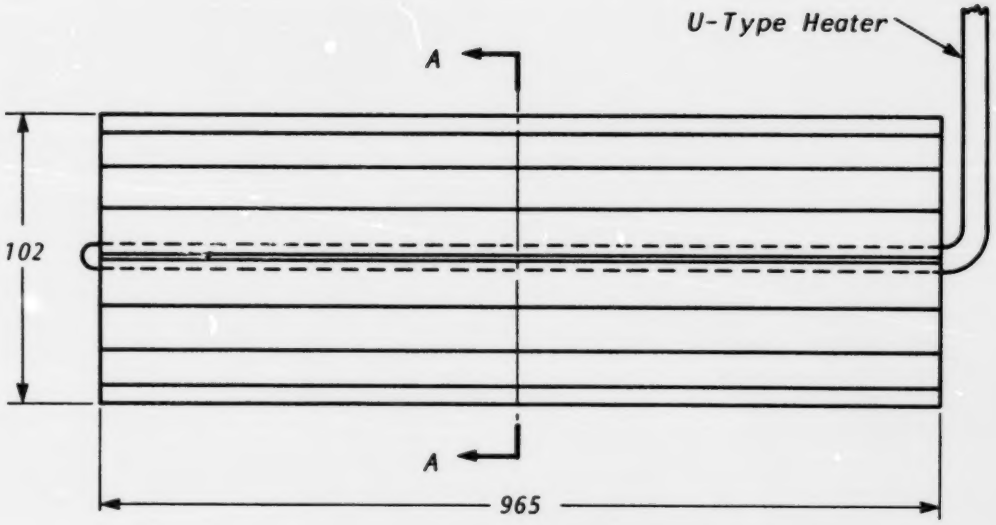


Side View

All Dimensions in mm

FIGURE 4

ELECTRICALLY SIMULATED DOUBLE FUEL BUNDLE
(PICKERING NGS DESIGN)

175088-RD

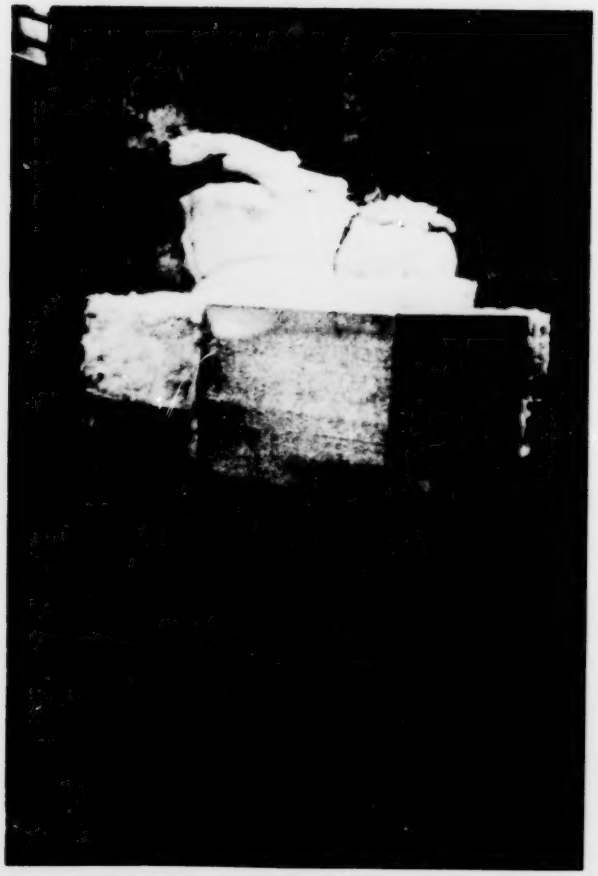
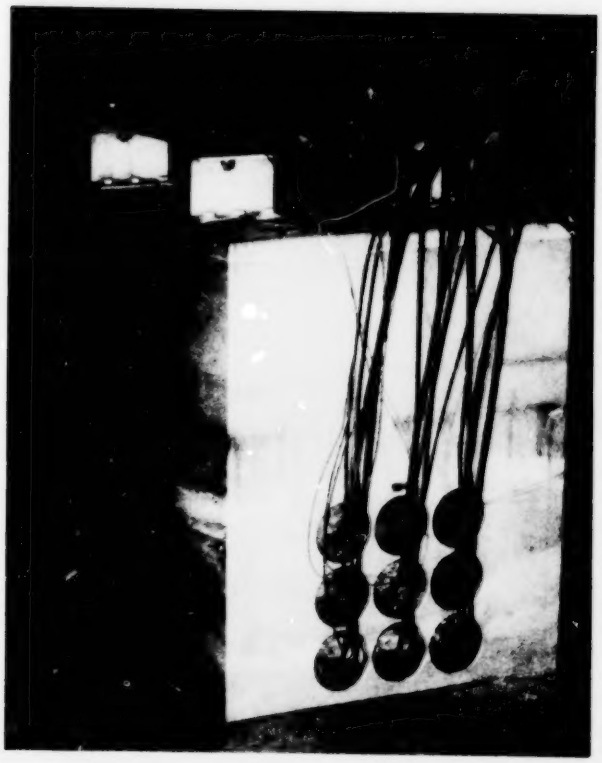
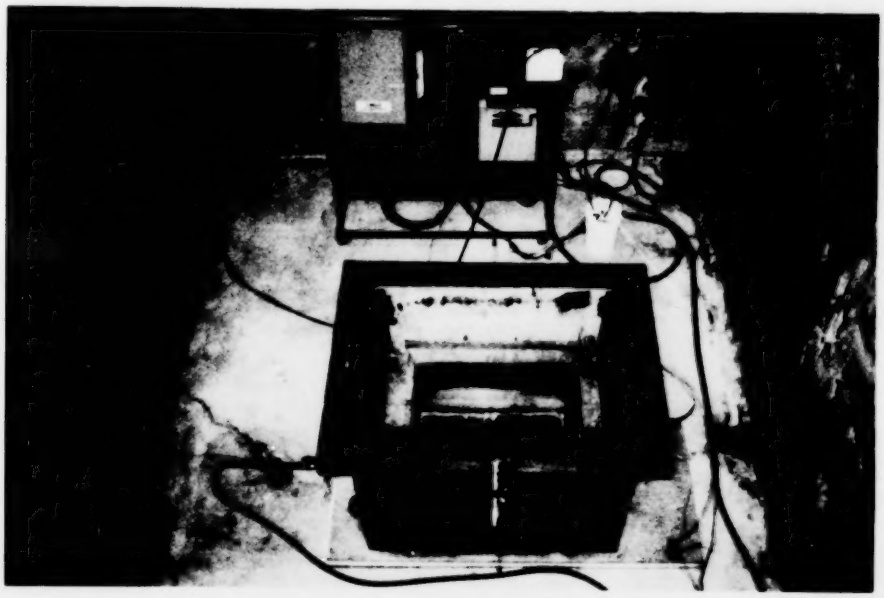


FIGURE 5
SIMULATED IMPACT LIMITER



Aluminum Basket and Simulated Fuel Bundles



Simulated Cask and Carbon Steel Liner

FIGURE 6

SIMULATED CASK AND CARBON STEEL LINER
WITH ALUMINUM BASKET REMOVED FROM THE CAVITY

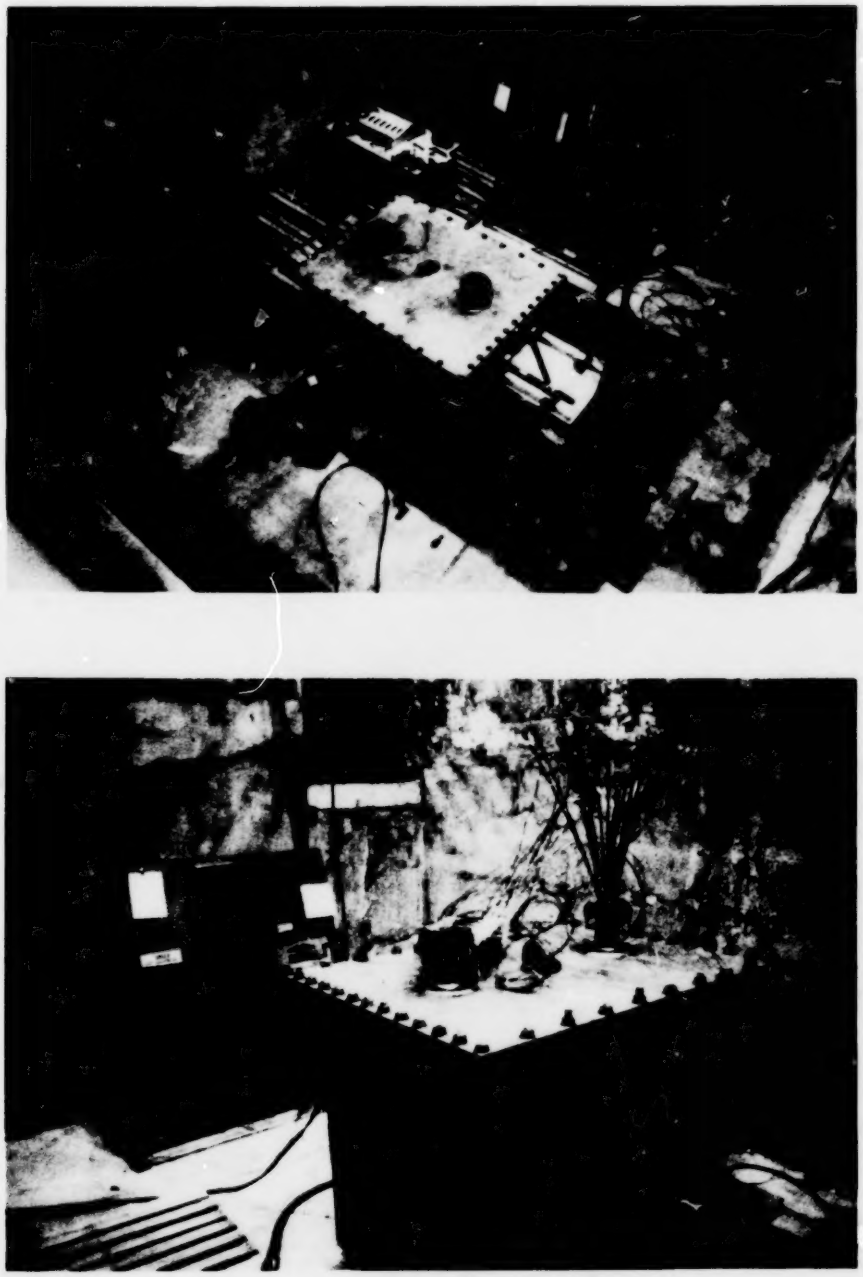


FIGURE 7

SIMULATED CASK WITH CARBON STEEL LINER
AND ALUMINUM BASKET INSIDE THE CAVITY

Heaters

Thermocouples

FIGURE 8

GLAND CONNECTORS FOR THERMOCOUPLES
AND ELECTRIC HEATERS

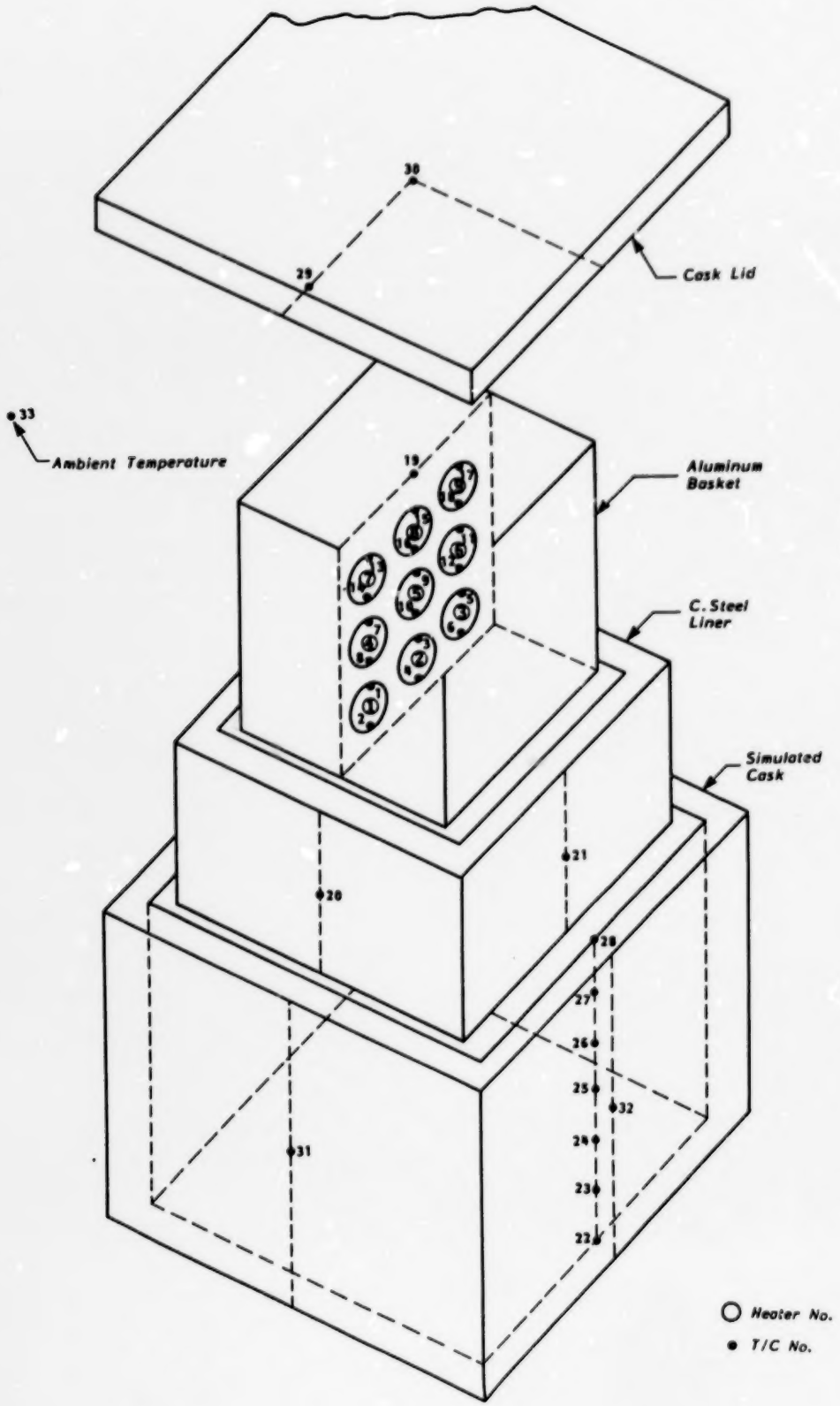


FIGURE 9

THERMOCOUPLE AND HEATER NUMBERING SCHEME

200820-RD

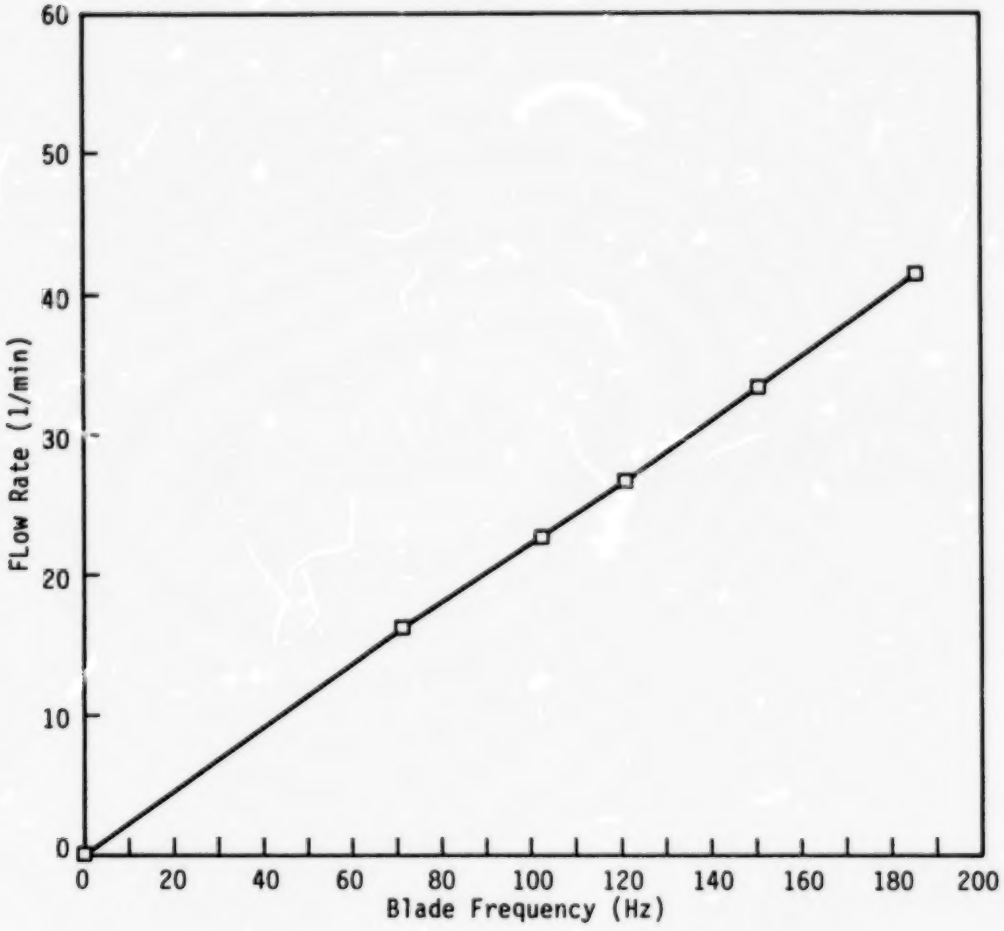


FIGURE 10
CALIBRATION OF WATER FLOW METER

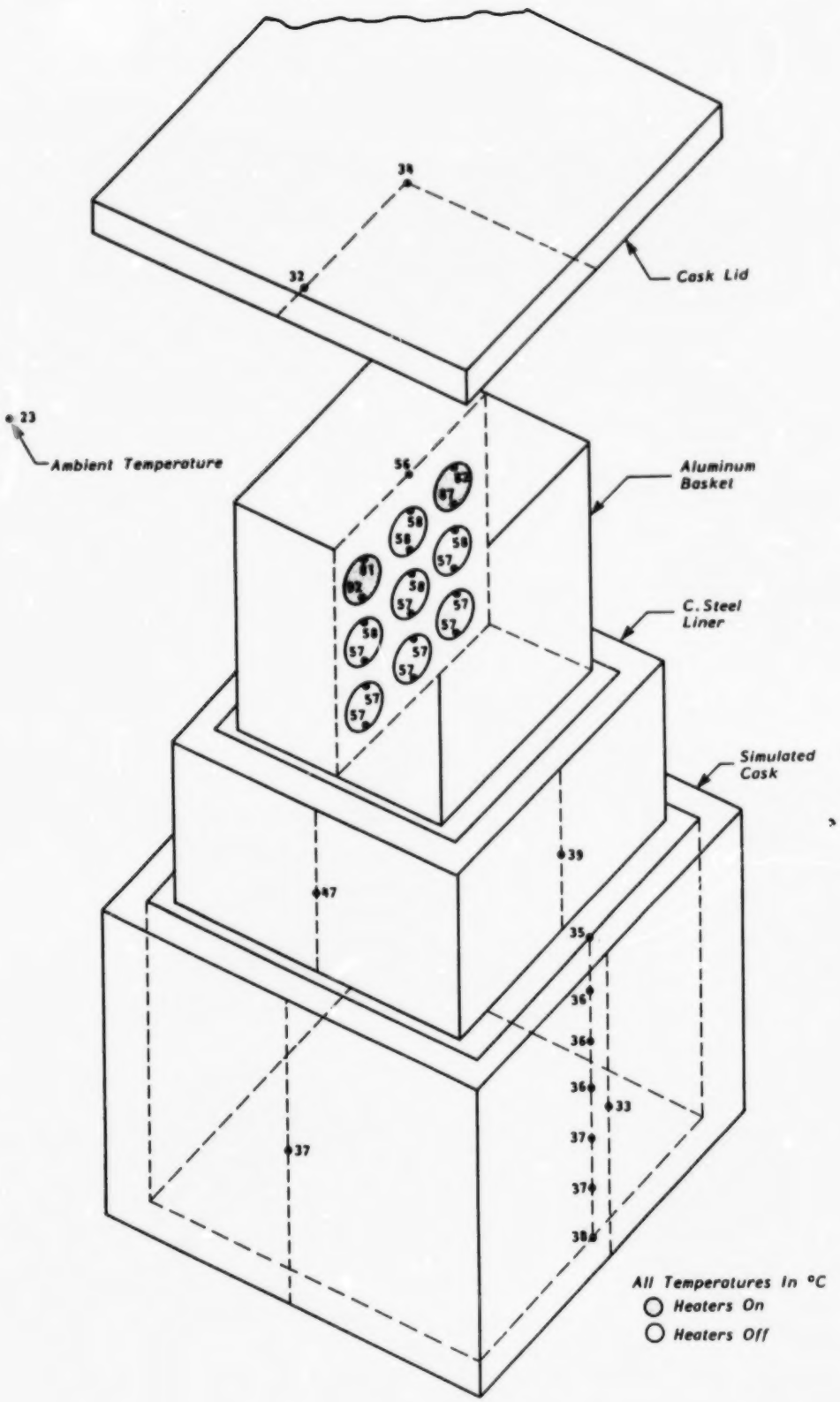


FIGURE 11

DRY CAVITY TEST WITH 4 BUNDLES AT 200 W/BUNDLE

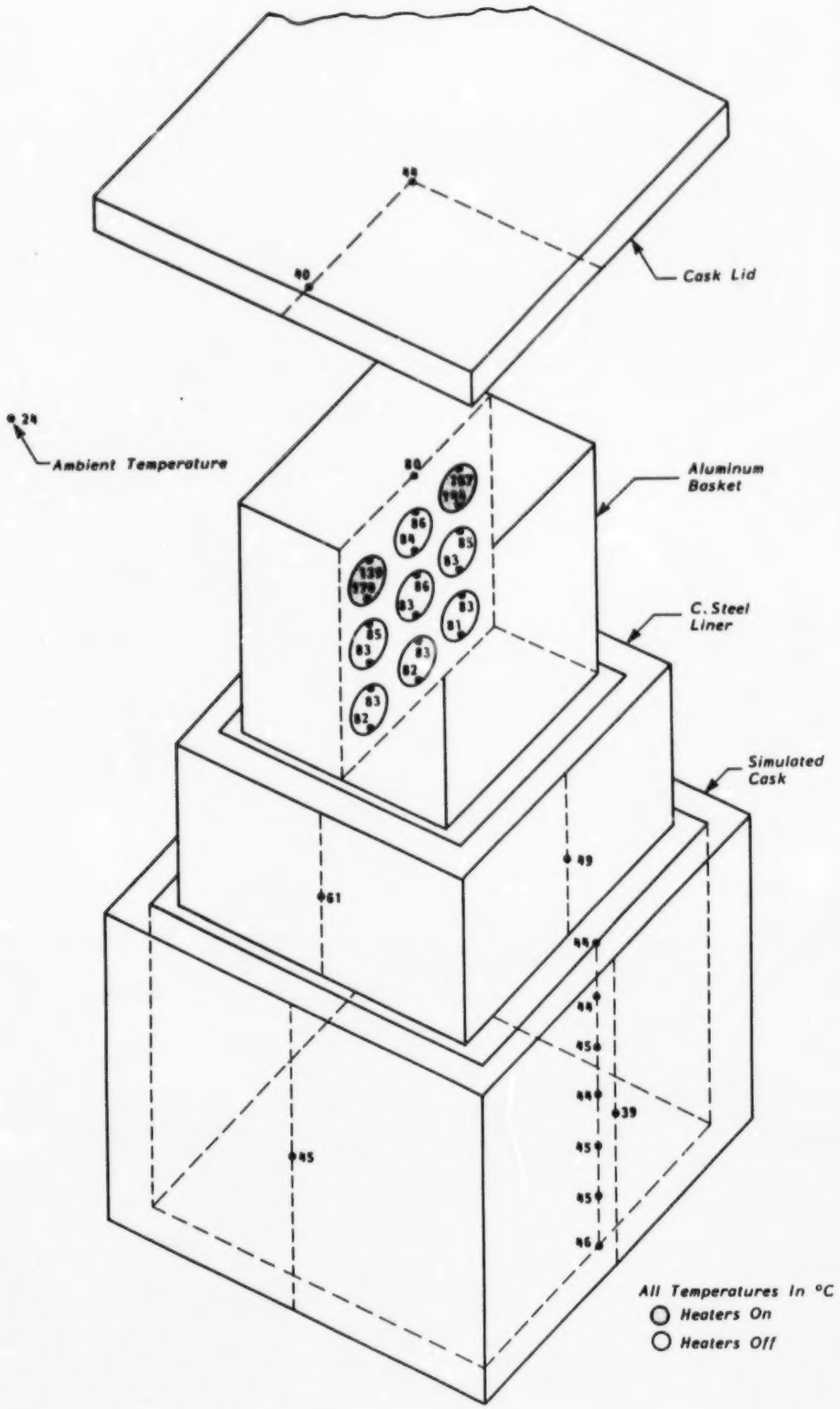


FIGURE 12

DRY CAVITY TEST WITH 4 BUNDLES AT 430 W/BUNDLE

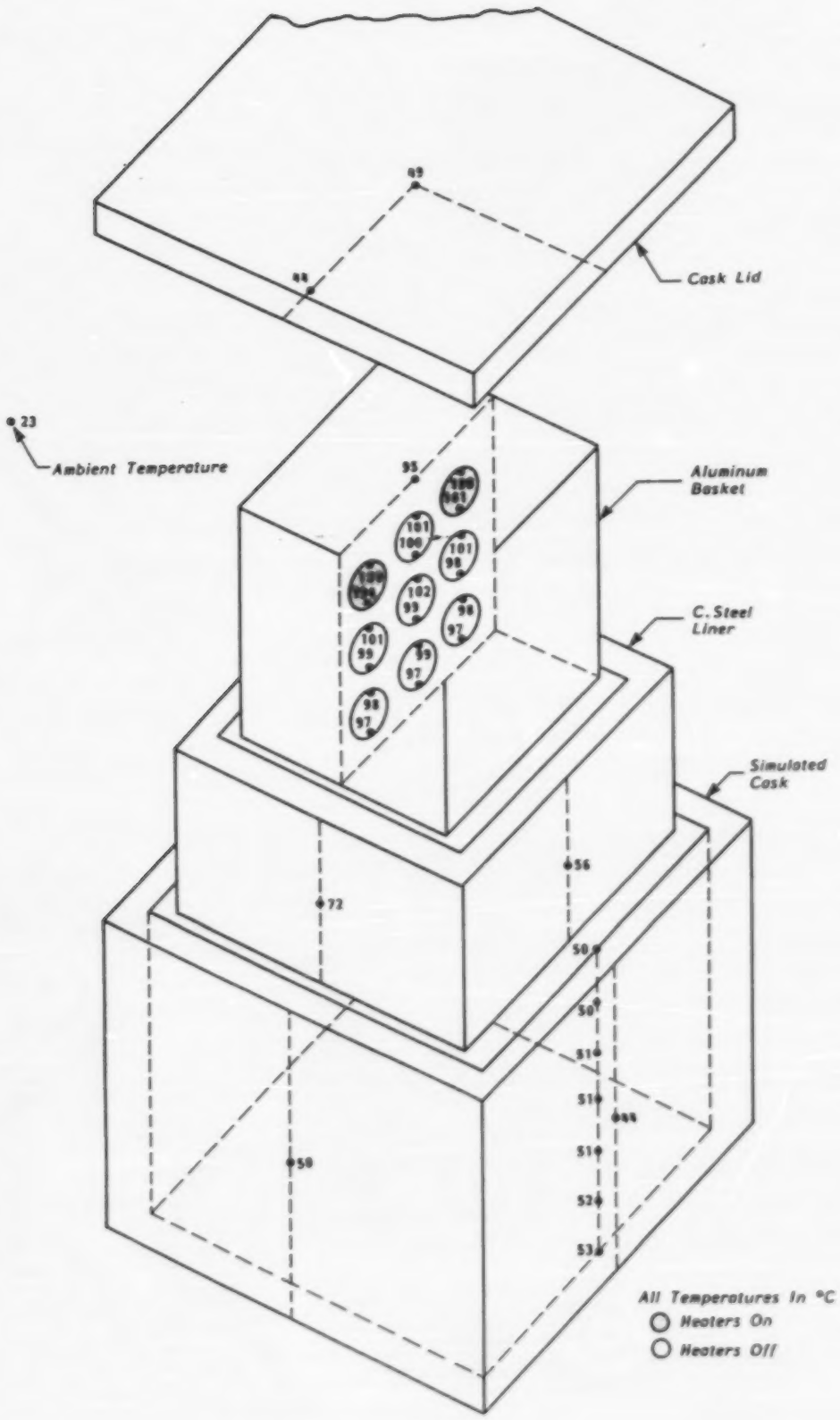


FIGURE 13

DRY CAVITY TEST WITH 4 BUNDLES AT 500 W/BUNDLE

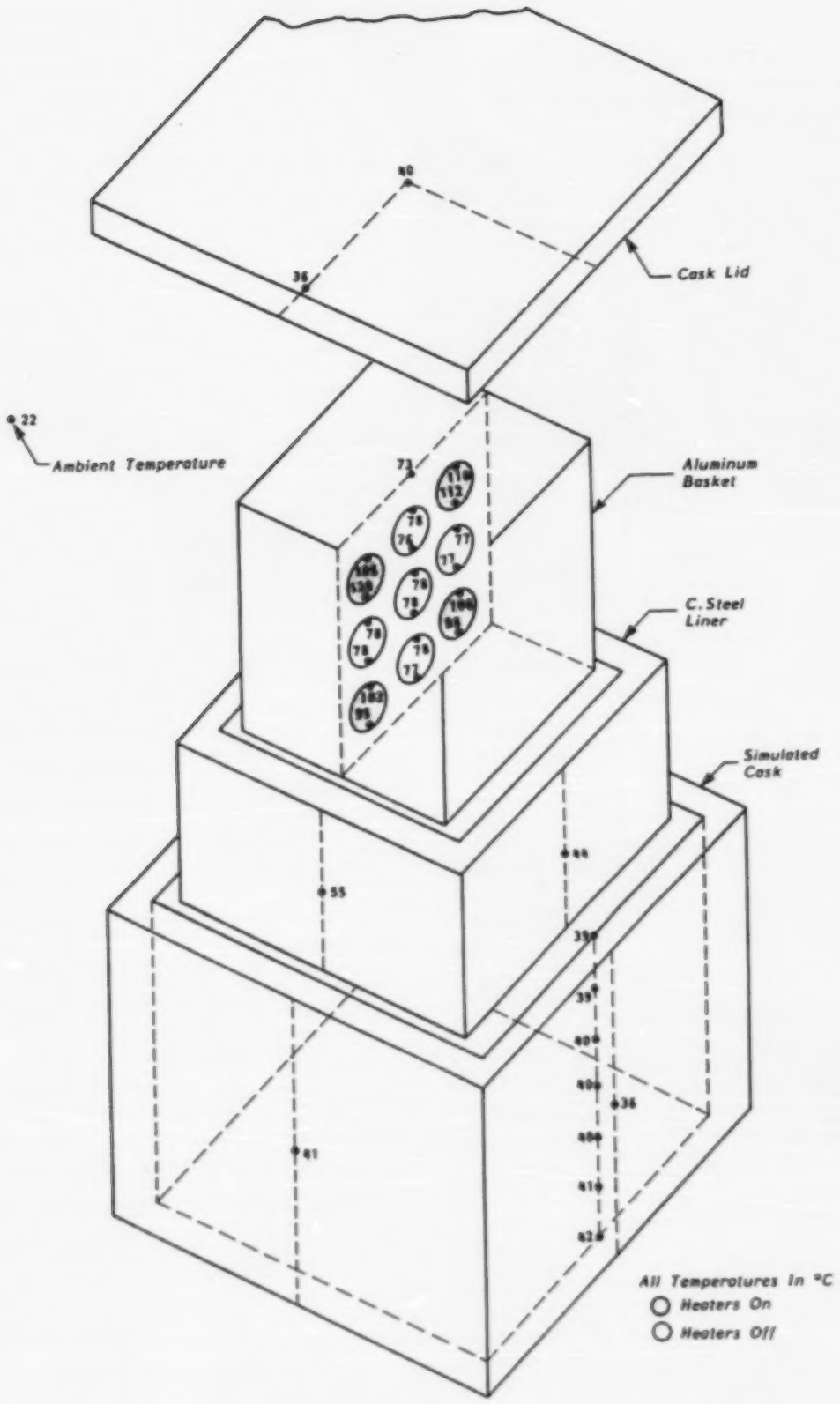


FIGURE 14

DRY CAVITY TEST WITH 8 BUNDLES AT 200 W/BUNDLE

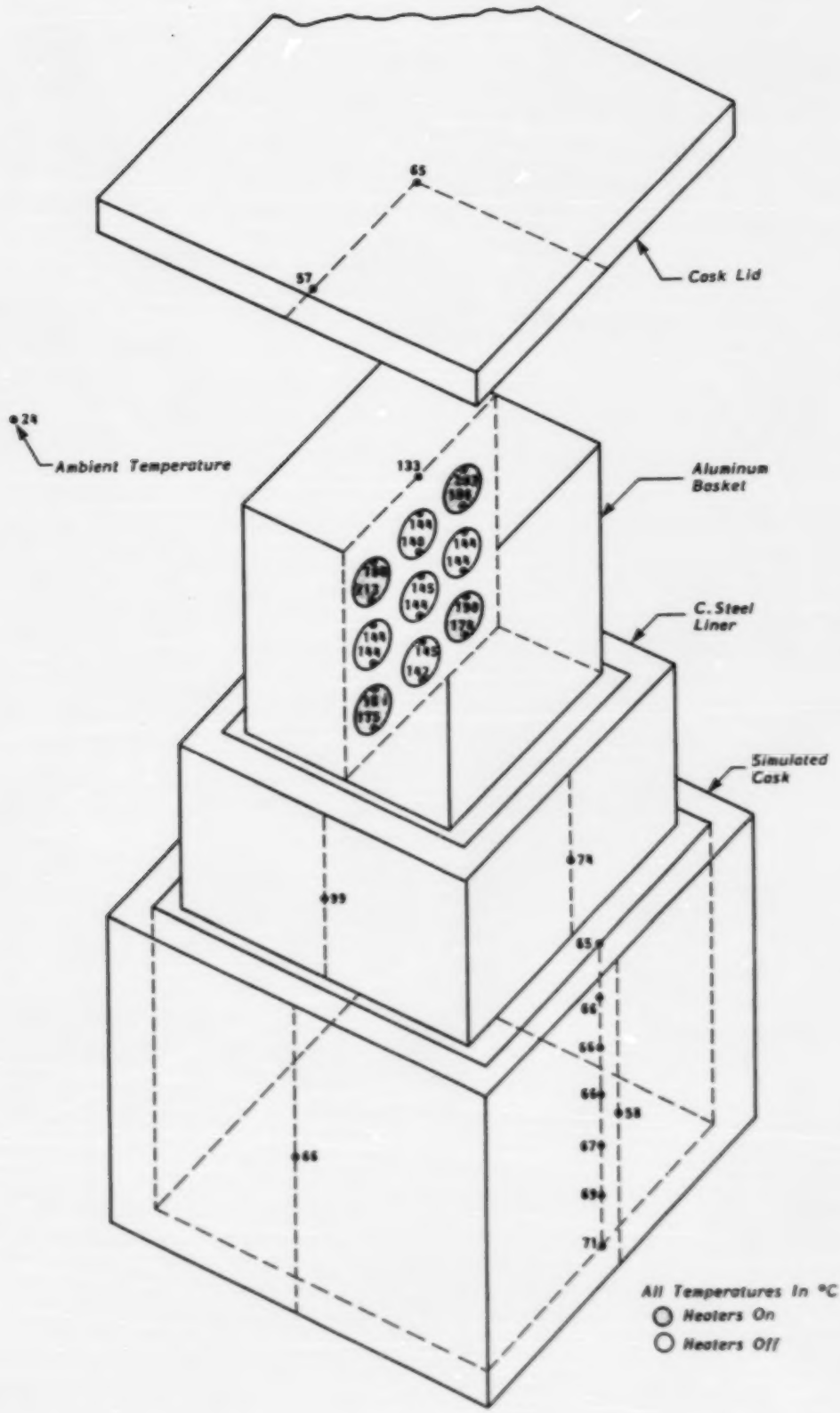


FIGURE 15

DRY CAVITY TEST WITH 8 BUNDLES AT 430 W/BUNDLE

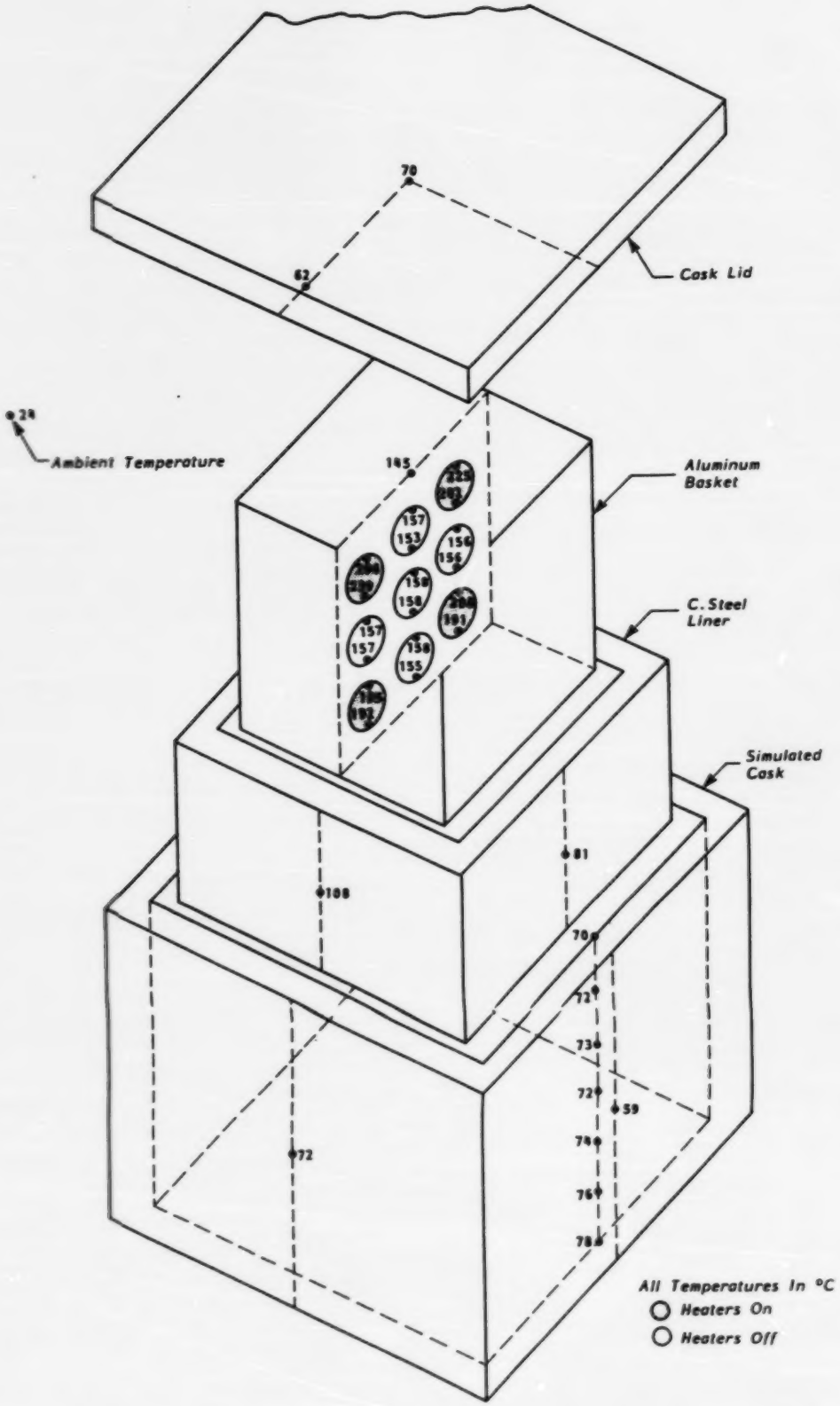


FIGURE 16

DRY CAVITY TEST WITH 8 BUNDLES AT 500 W/BUNDLE

200826-RD

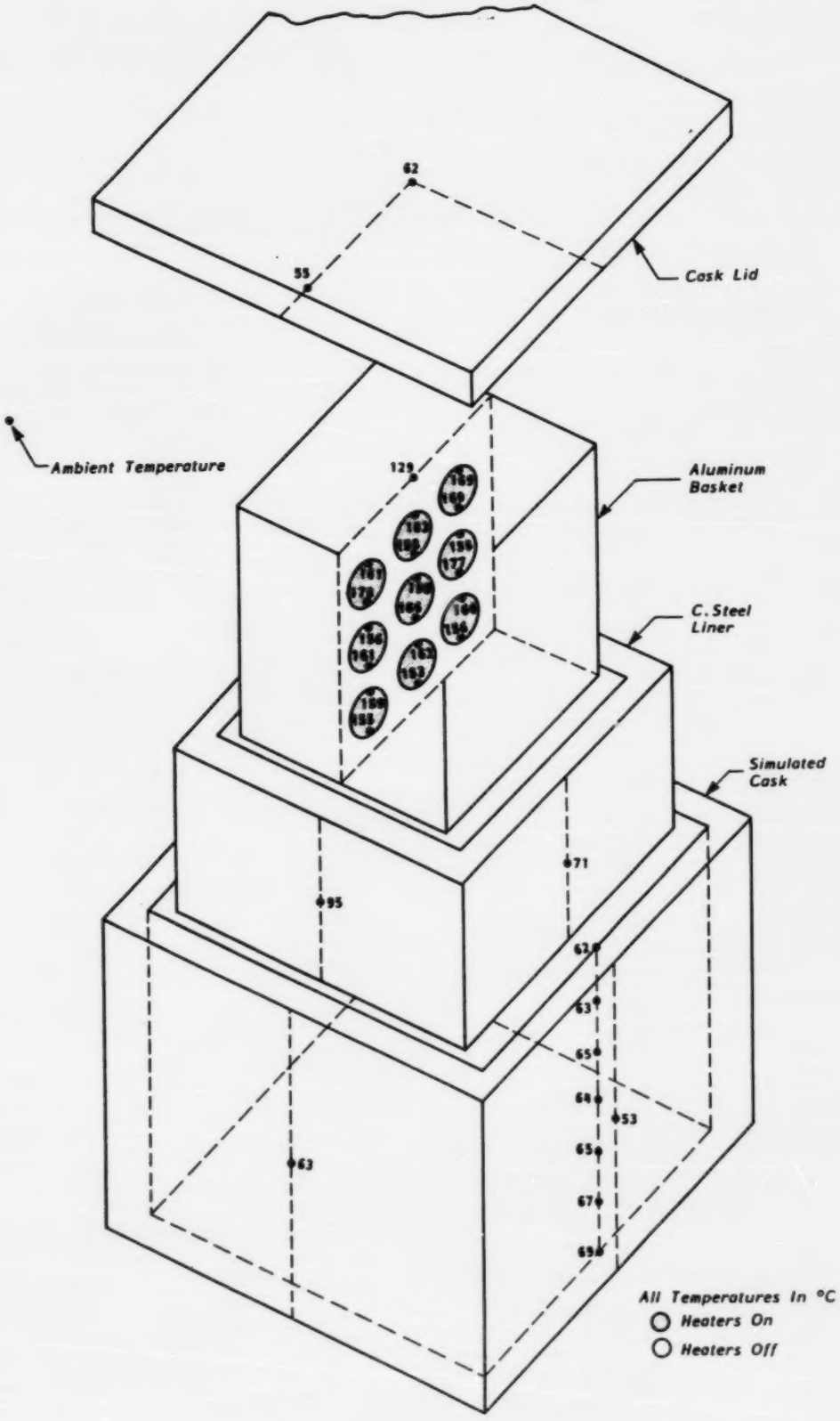


FIGURE 17

DRY CAVITY TEST WITH 18 BUNDLES AT 200 W/BUNDLE

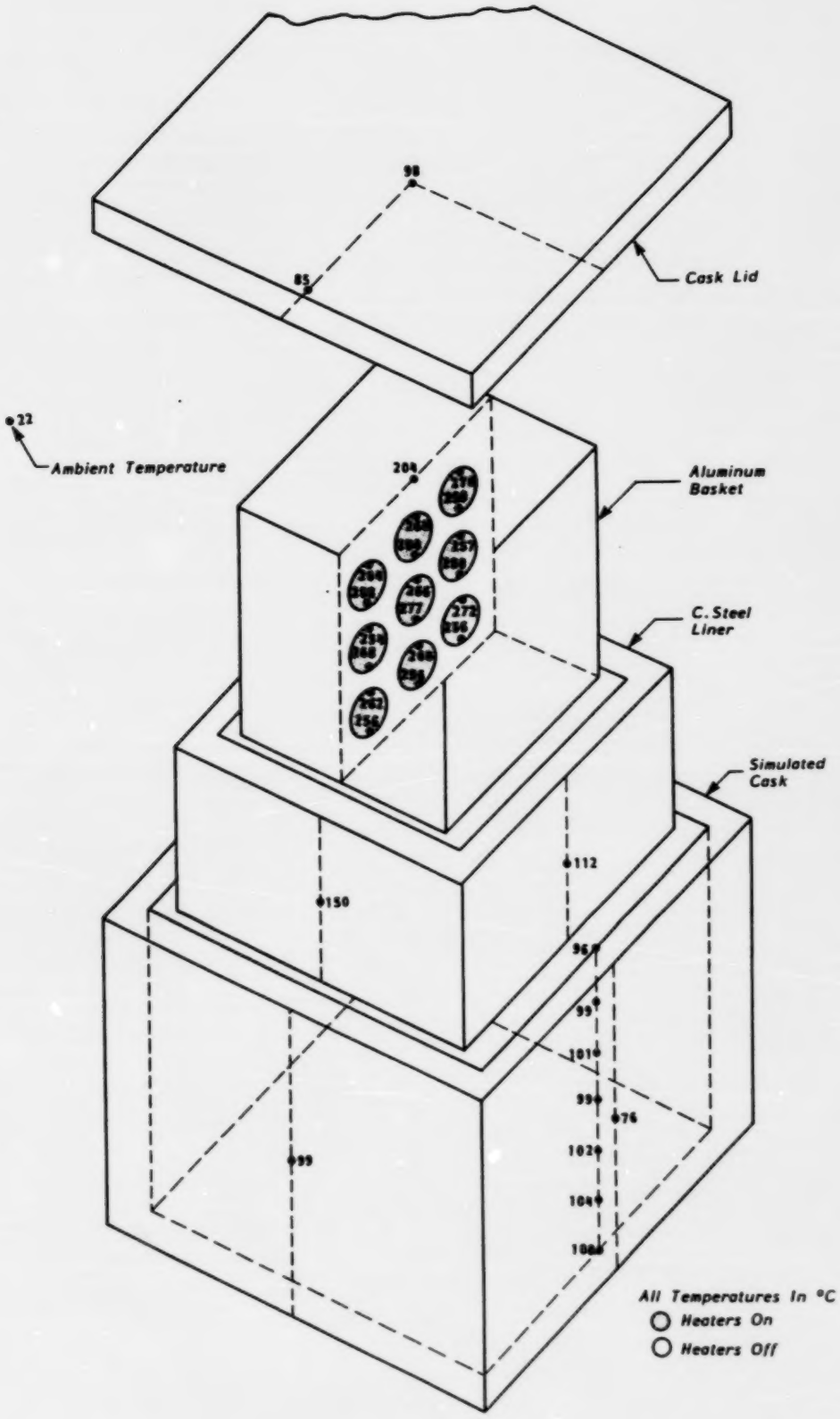


FIGURE 18

DRY CAVITY TEST WITH 18 BUNDLES AT 430 W/BUNDLE

200828-RD

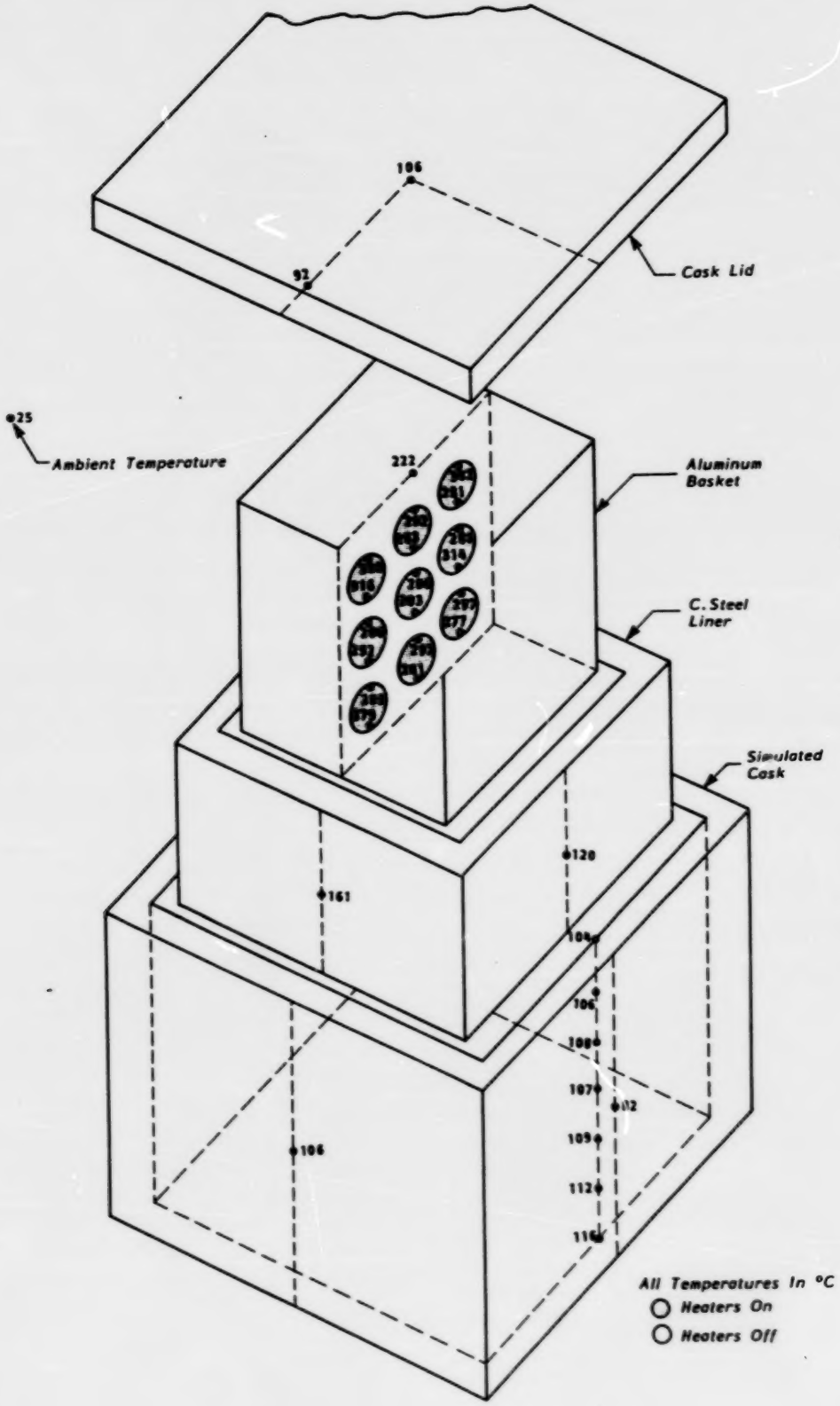


FIGURE 19

DRY CAVITY TEST WITH 18 BUNDLES AT 500 W/BUNDLE

200829-RD

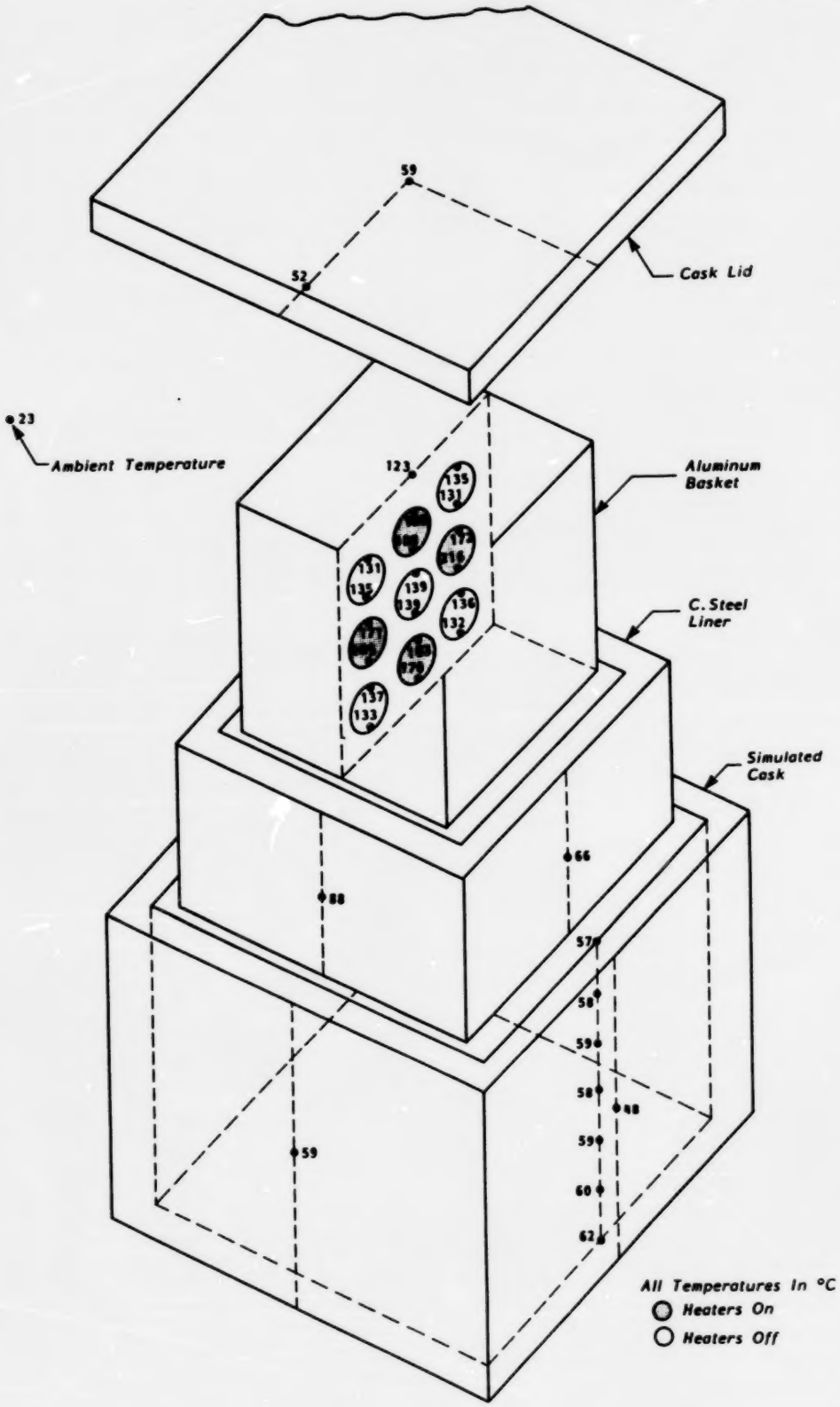


FIGURE 20

DRY CAVITY TEST WITH 8 BUNDLES AT 500 W/BUNDLE
(CROSS ARRANGEMENT)

200830-RD

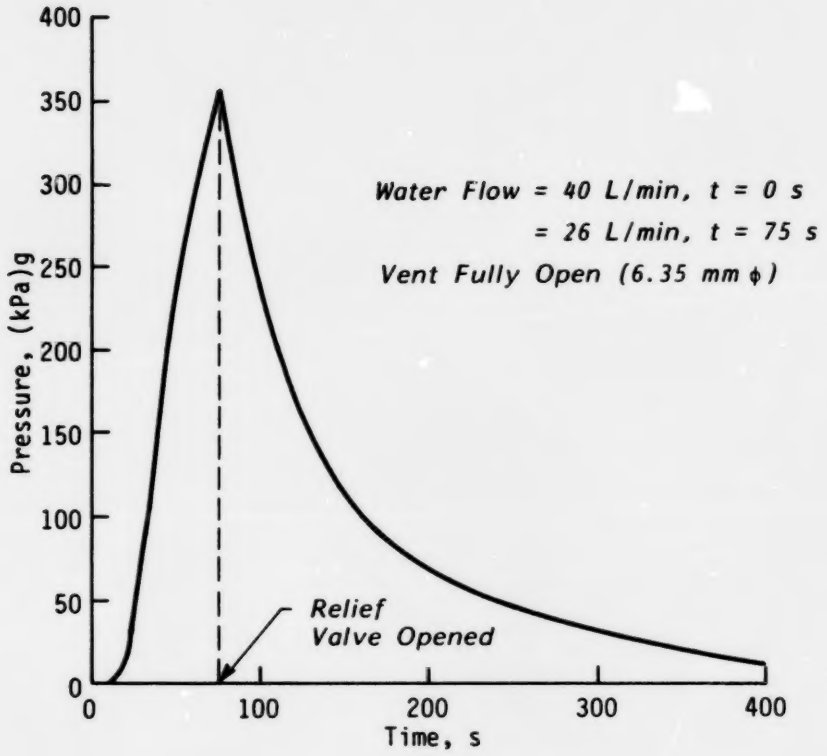


FIGURE 21

CAVITY PRESSURE DURING CAVITY REFLOOD TEST WITH 18 BUNDLES AT 500 W/BUNDLE

175094-RD

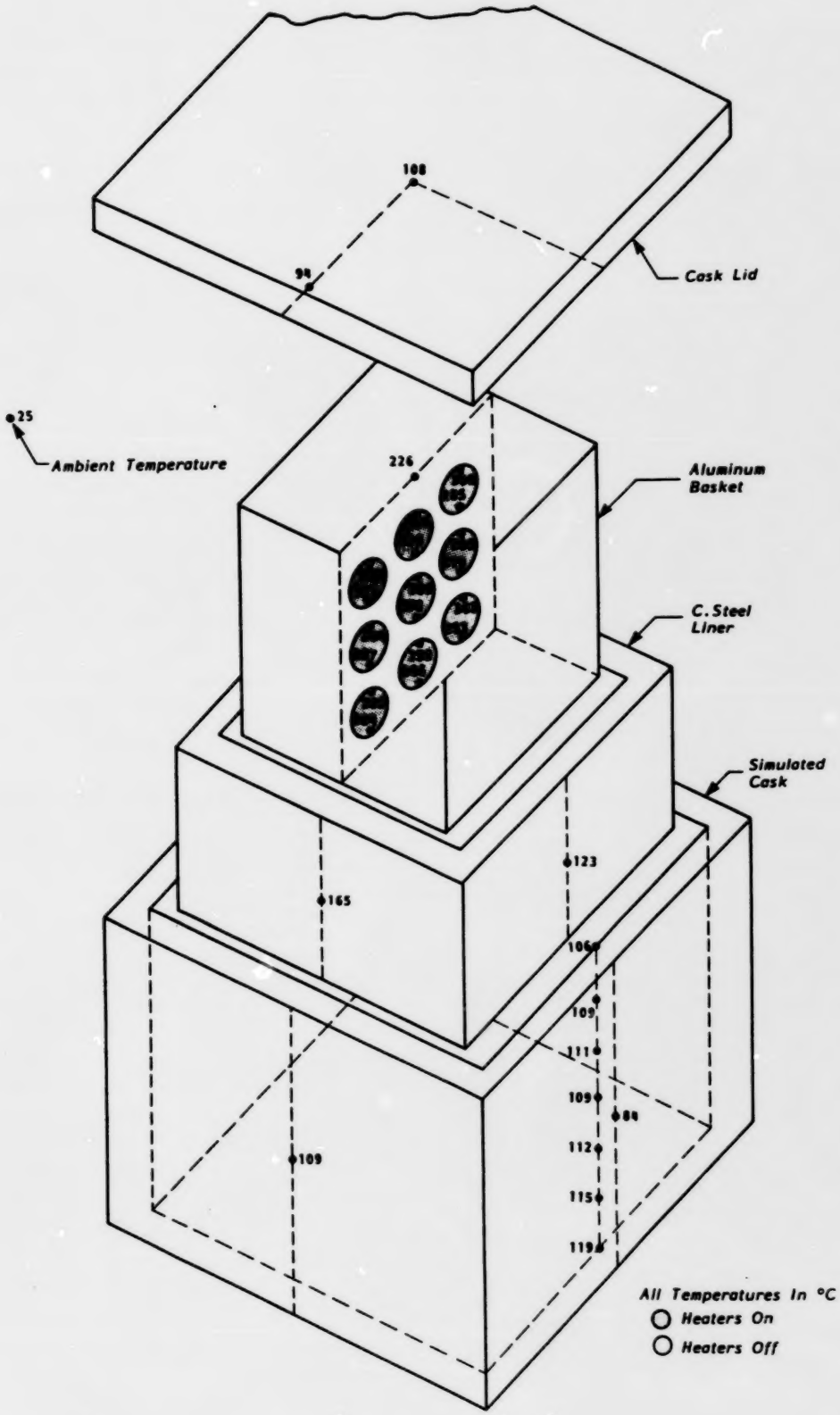


FIGURE 22

CAVITY REFLOOD TEST WITH 18 BUNDLES AT 500 W/BUNDLE
BEFORE ADMITTING WATER TO THE CAVITY

200831-RD

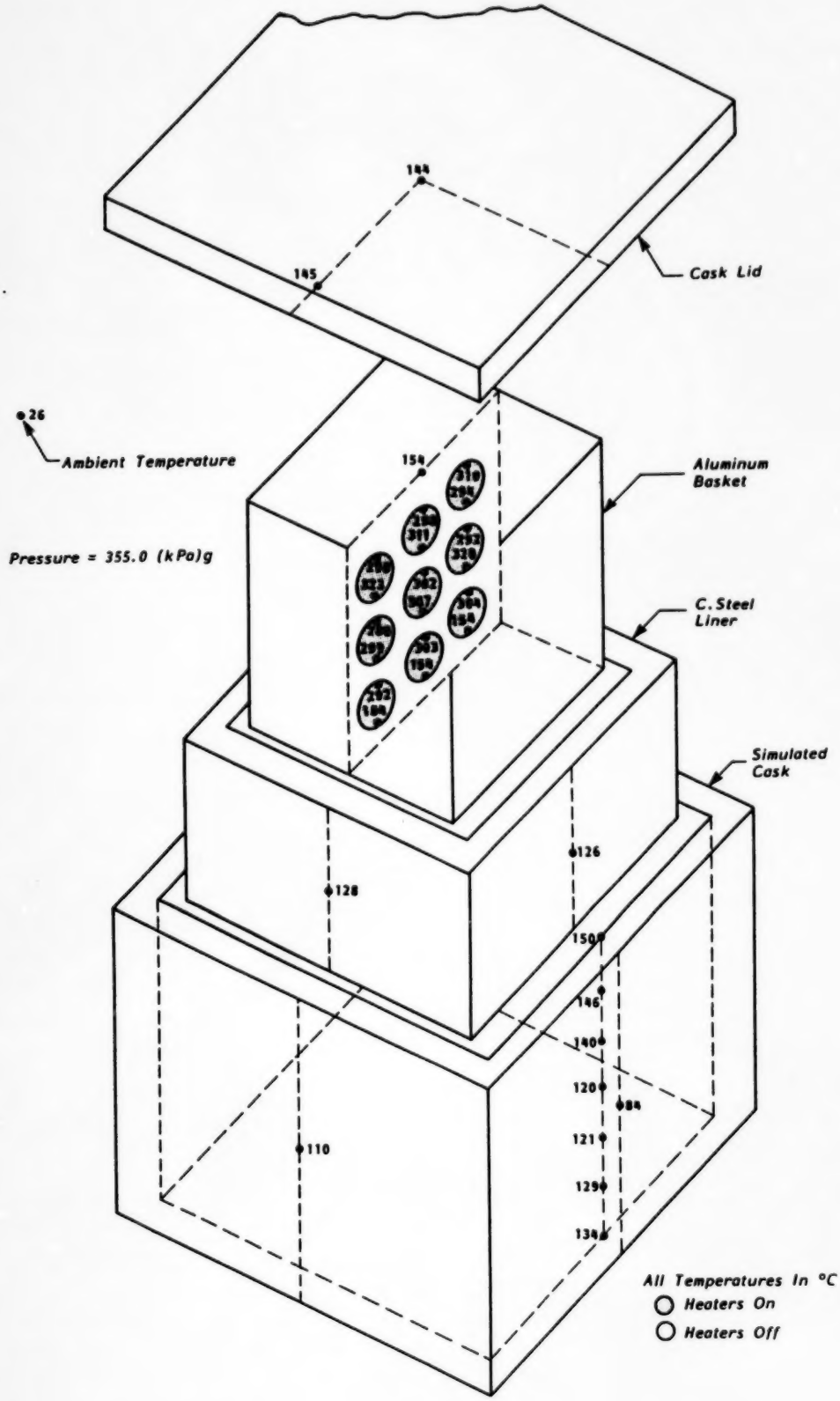


FIGURE 23

CAVITY REFLOOD TEST WITH 18 BUNDLES AT 500 W/BUNDLE WHEN RELEAF VALVE OPENED

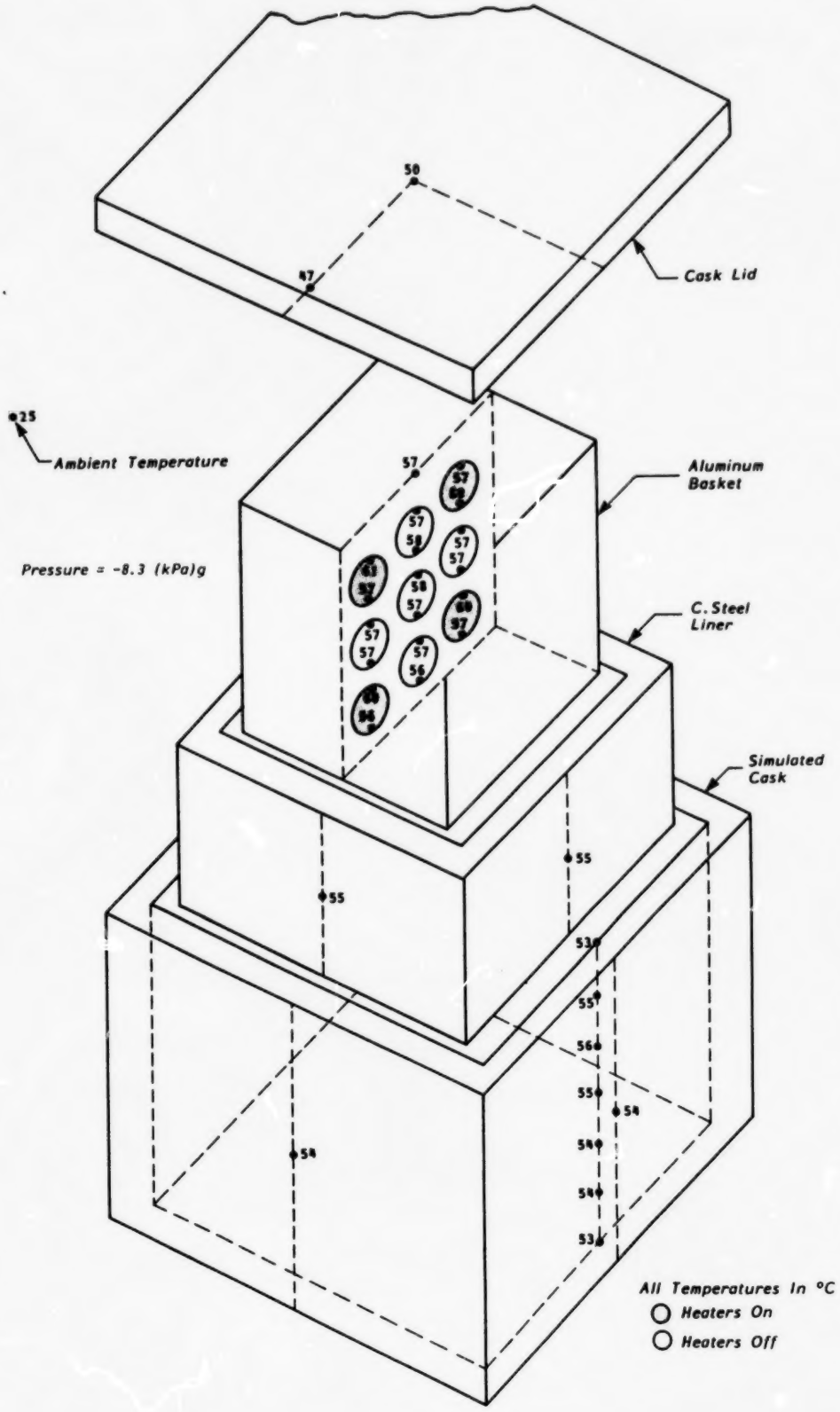


FIGURE 24

WATER CAVITY TEST WITH 8 BUNDLES AT 200 W/BUNDLE

200833-RD

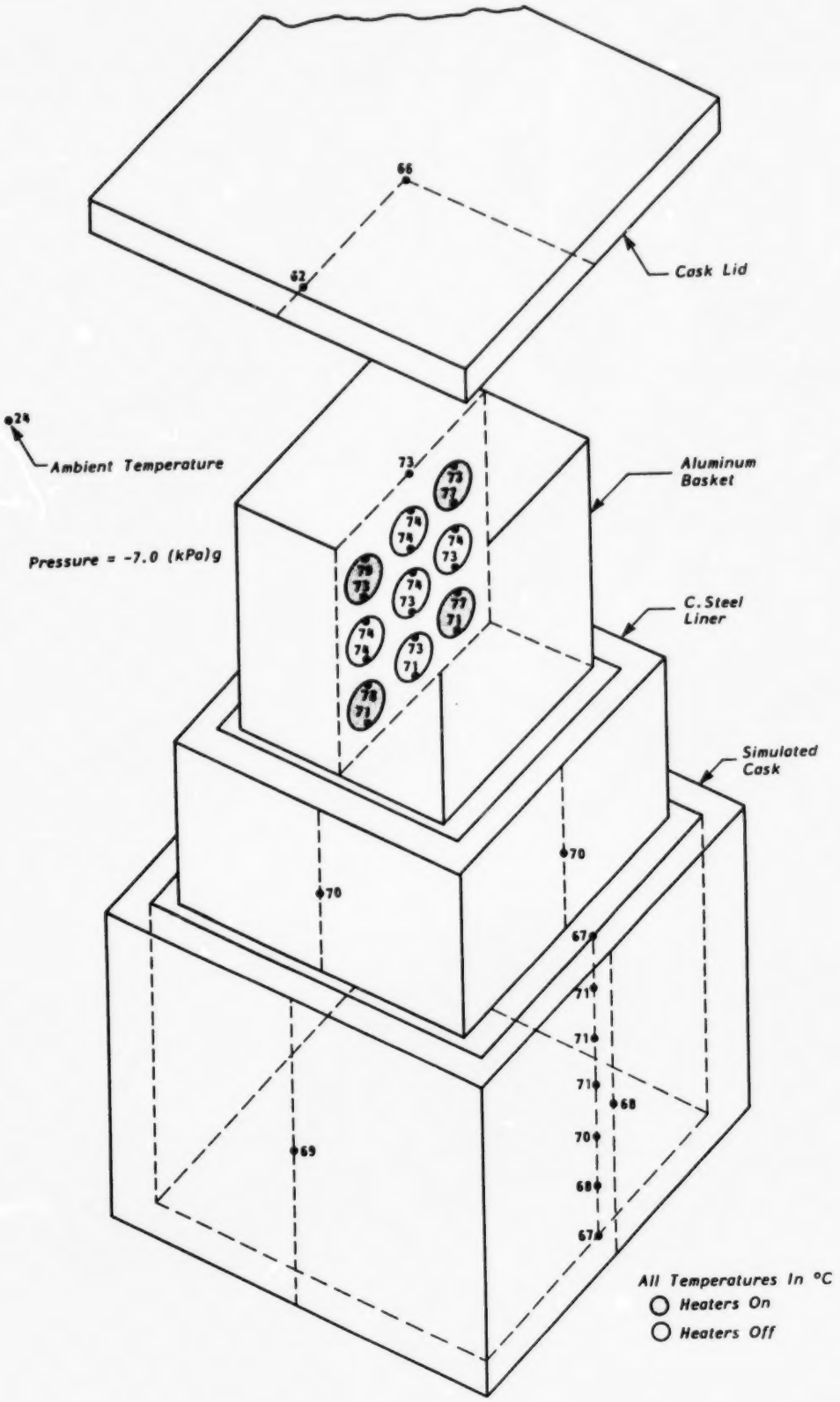


FIGURE 25

WATER CAVITY TEST WITH 8 BUNDLES AT 500 W/BUNDLE

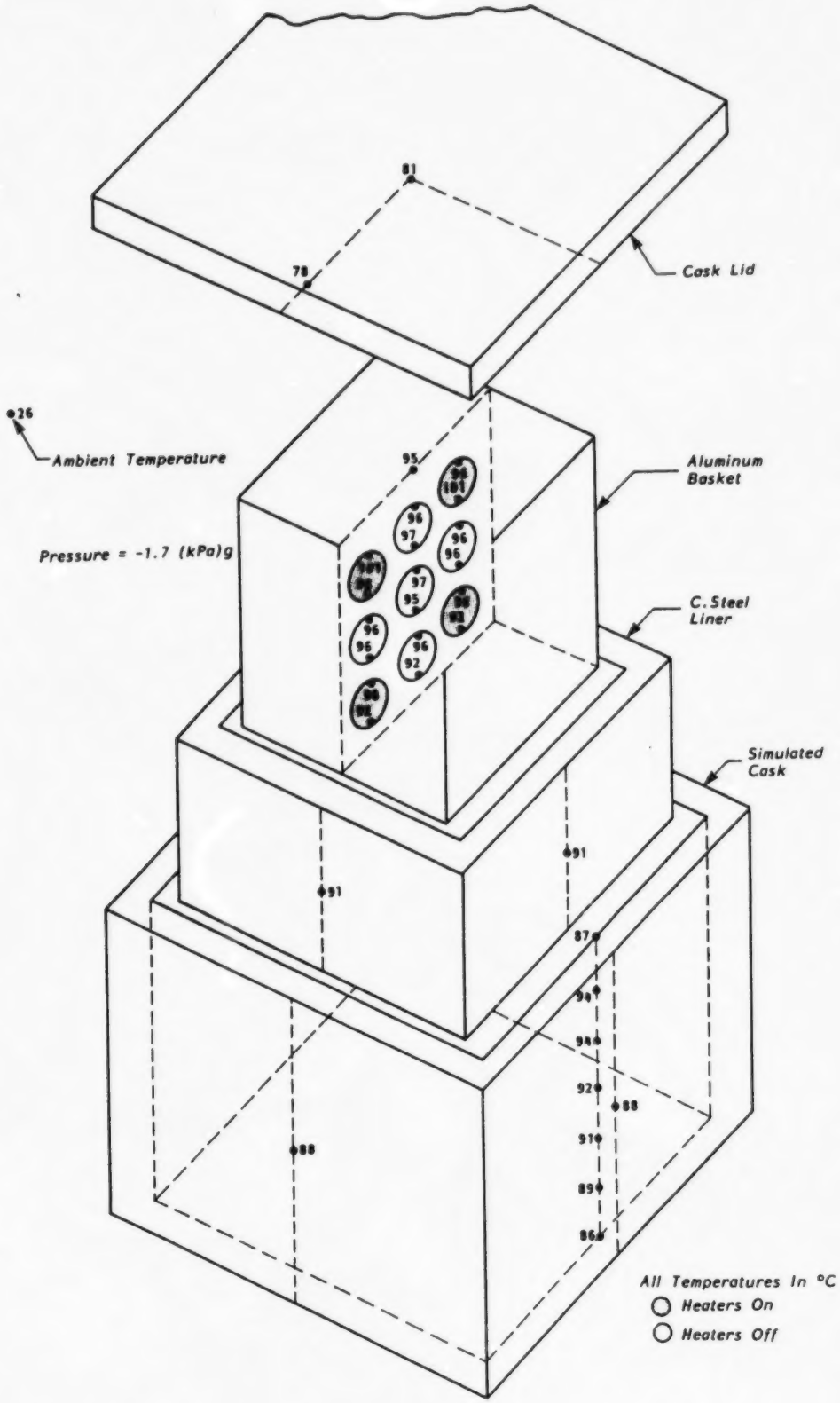


FIGURE 26

WATER CAVITY TEST WITH 8 BUNDLES AT 900 W/BUNDLE

200835-RD

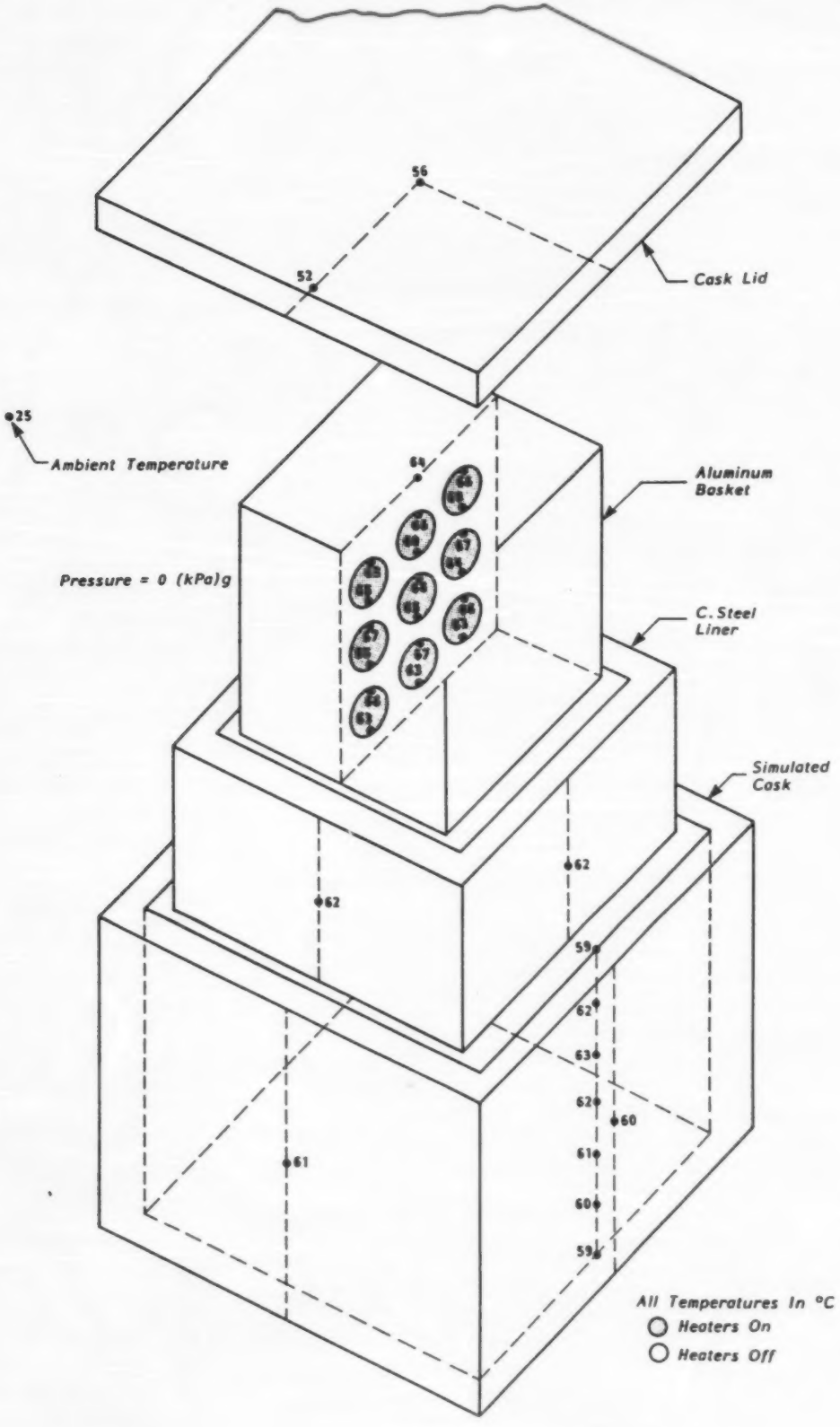


FIGURE 27
WATER CAVITY TEST WITH 18 BUNDLES AT 200 W/BUNDLE

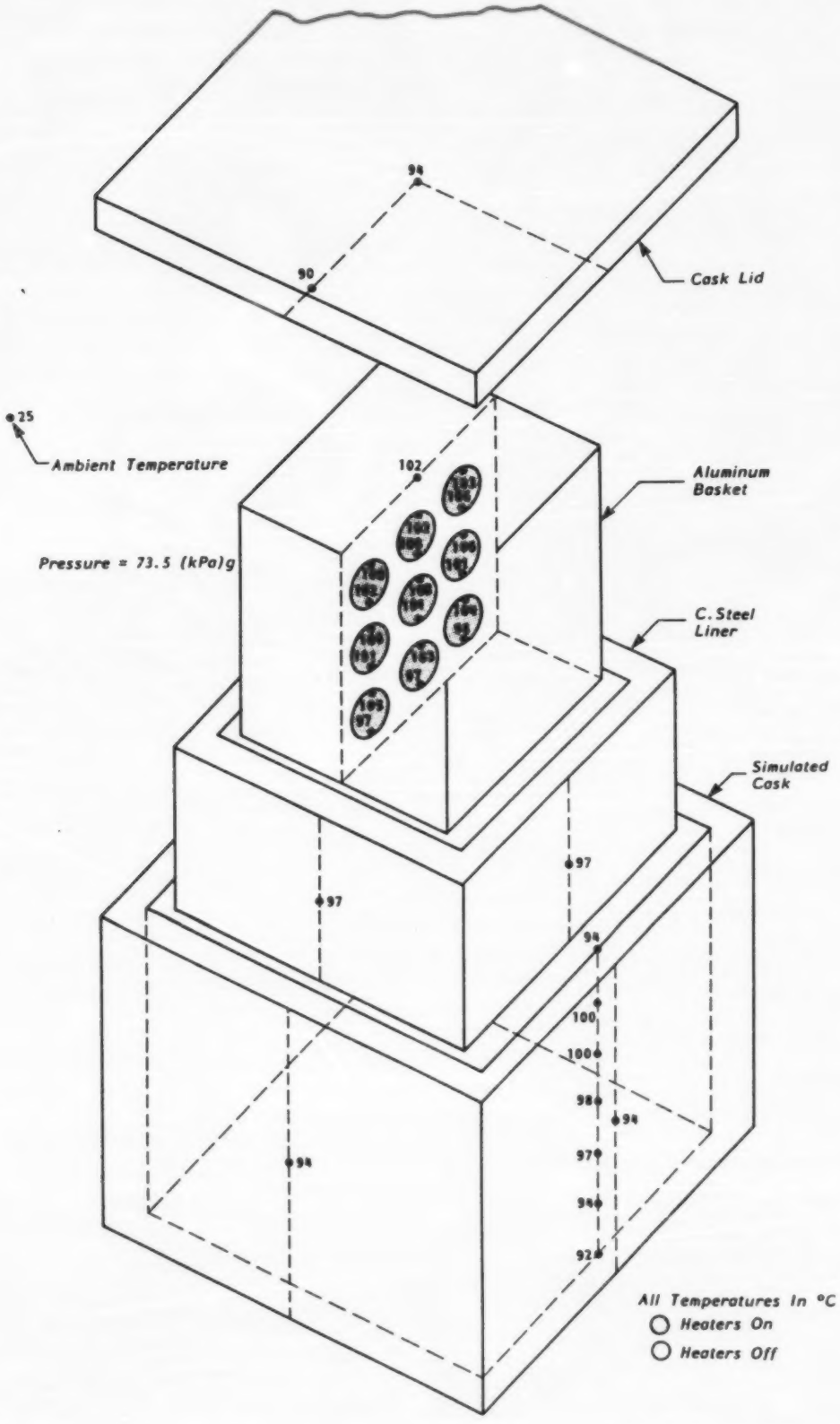


FIGURE 28

WATER CAVITY TEST WITH 18 BUNDLES AT 500 W/BUNDLE

200837-RD

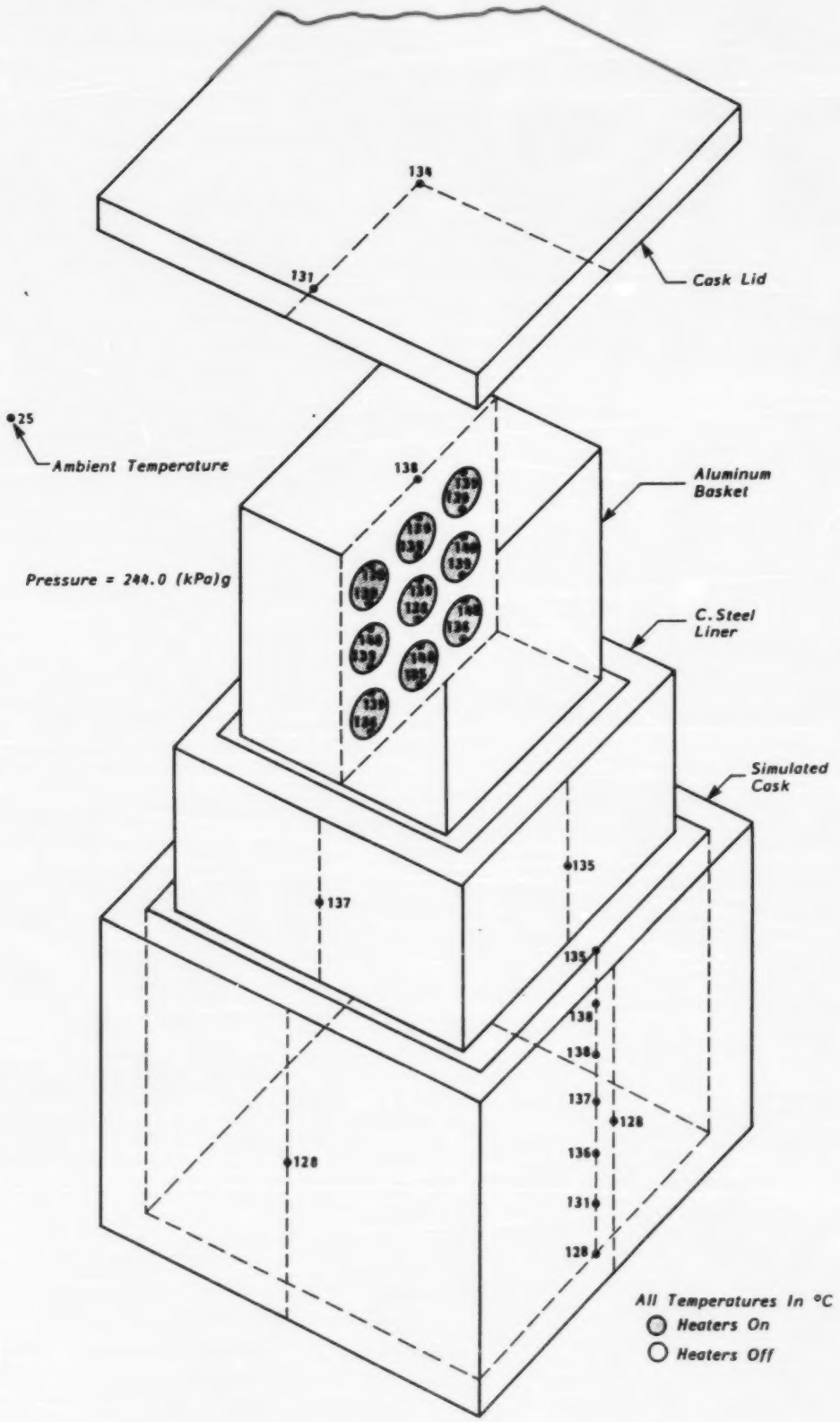


FIGURE 29

WATER CAVITY TEST WITH 18 BUNDLES AT 900 W/BUNDLE

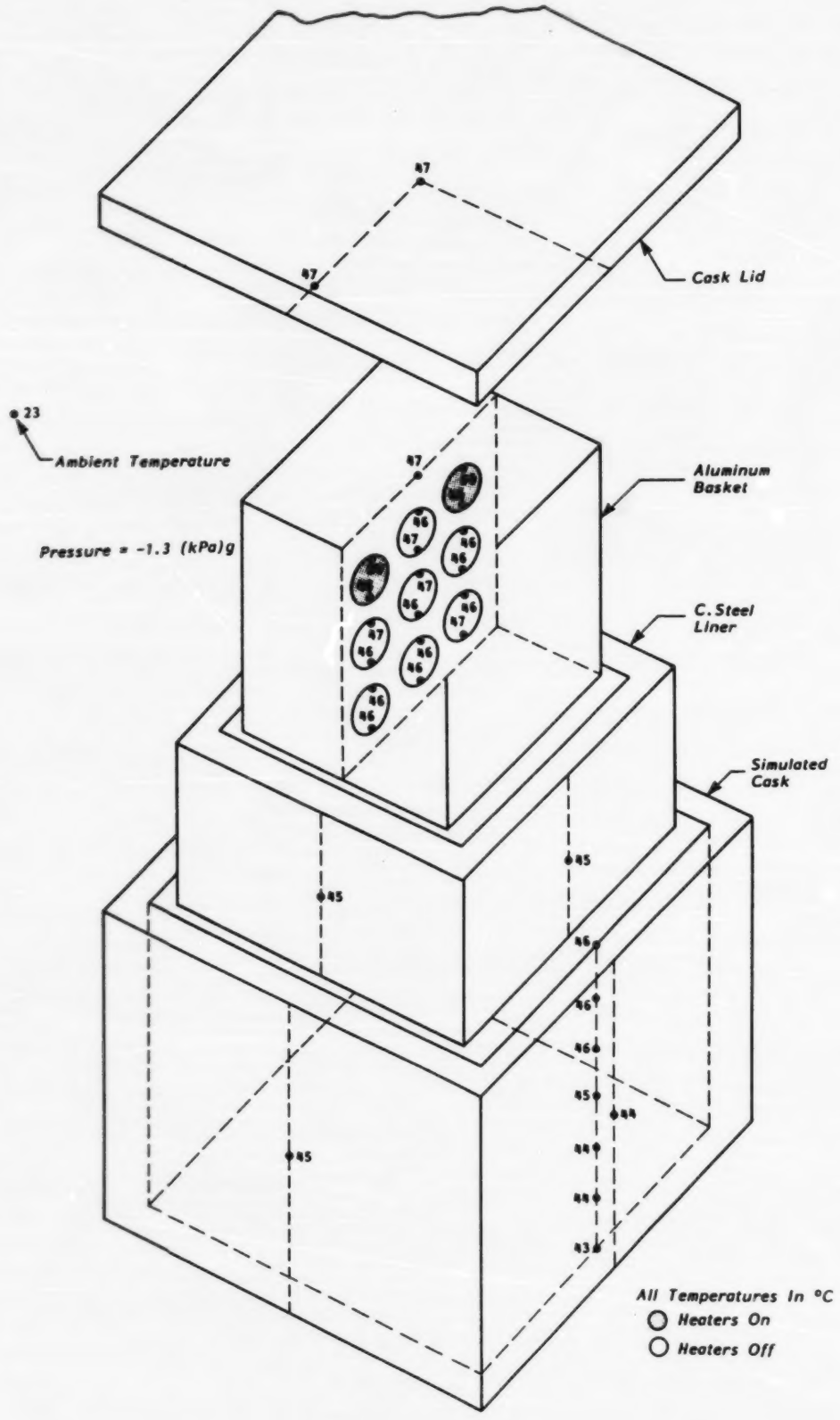


FIGURE 30

WATER CAVITY TEST WITH 4 BUNDLES AT 200 W/BUNDLE
AND WITH IMPACT LIMITER

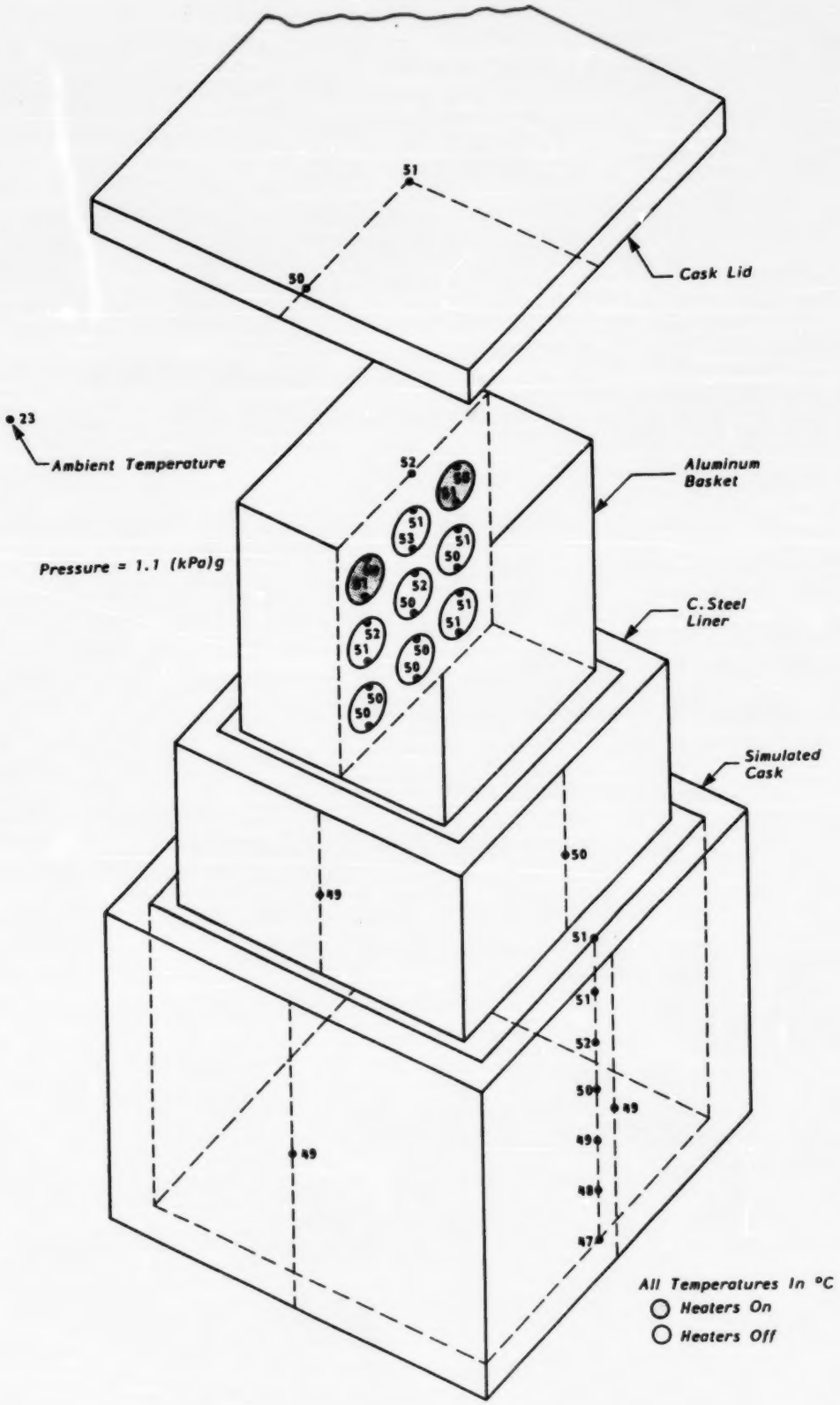


FIGURE 31

WATER CAVITY TEST WITH 4 BUNDLES AT 500 W/BUNDLE AND WITH IMPACT LIMITER

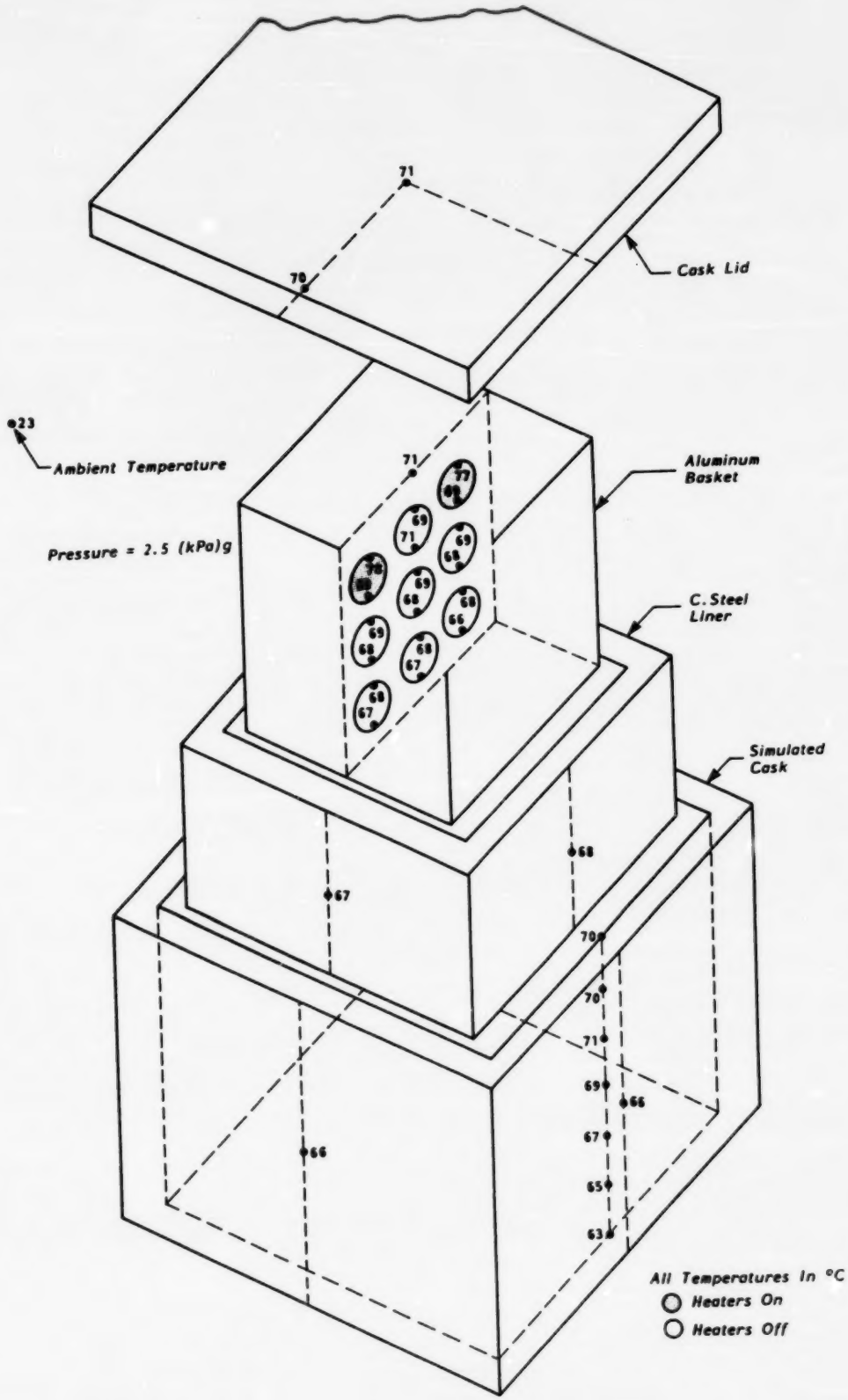


FIGURE 32

WATER CAVITY TEST WITH 4 BUNDLES AT 700 W/BUNDLE AND WITH IMPACT LIMITER

200841-RD

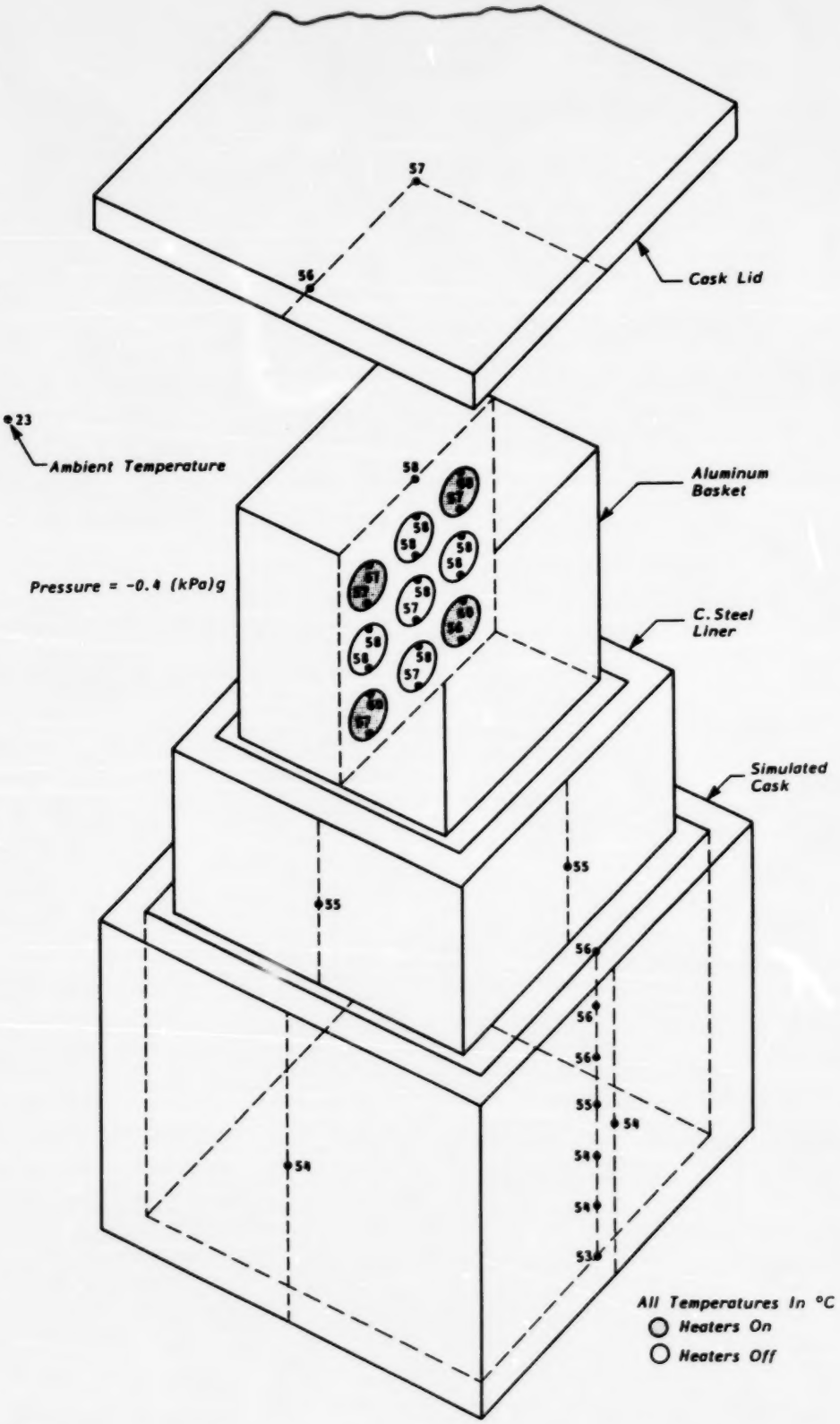


FIGURE 33

WATER CAVITY TEST WITH 8 BUNDLES AT 200 W/BUNDLE
AND WITH IMPACT LIMITER

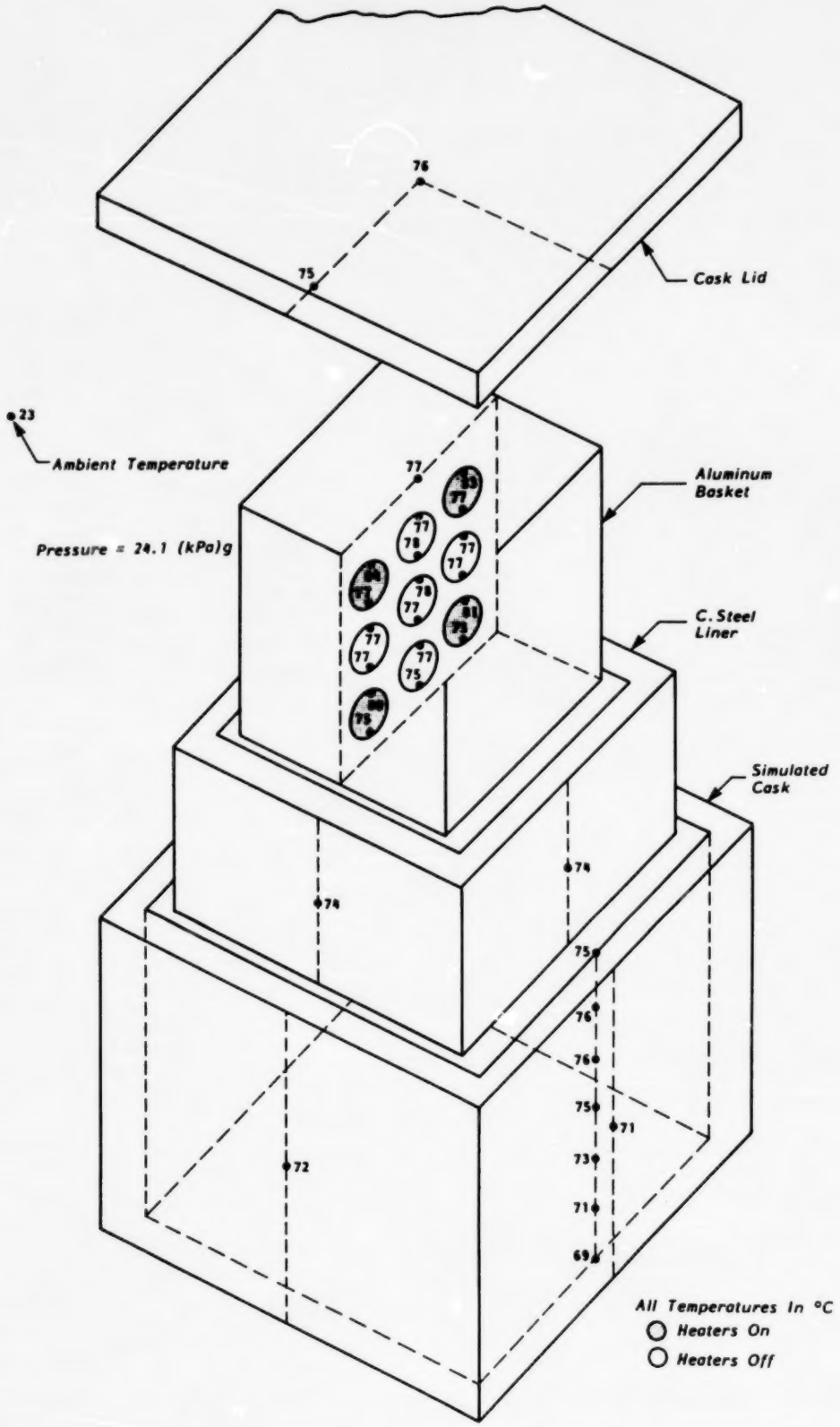


FIGURE 34

WATER CAVITY TEST WITH 8 BUNDLES AT 500 W/BUNDLE AND WITH IMPACT LIMITER

200843-RD

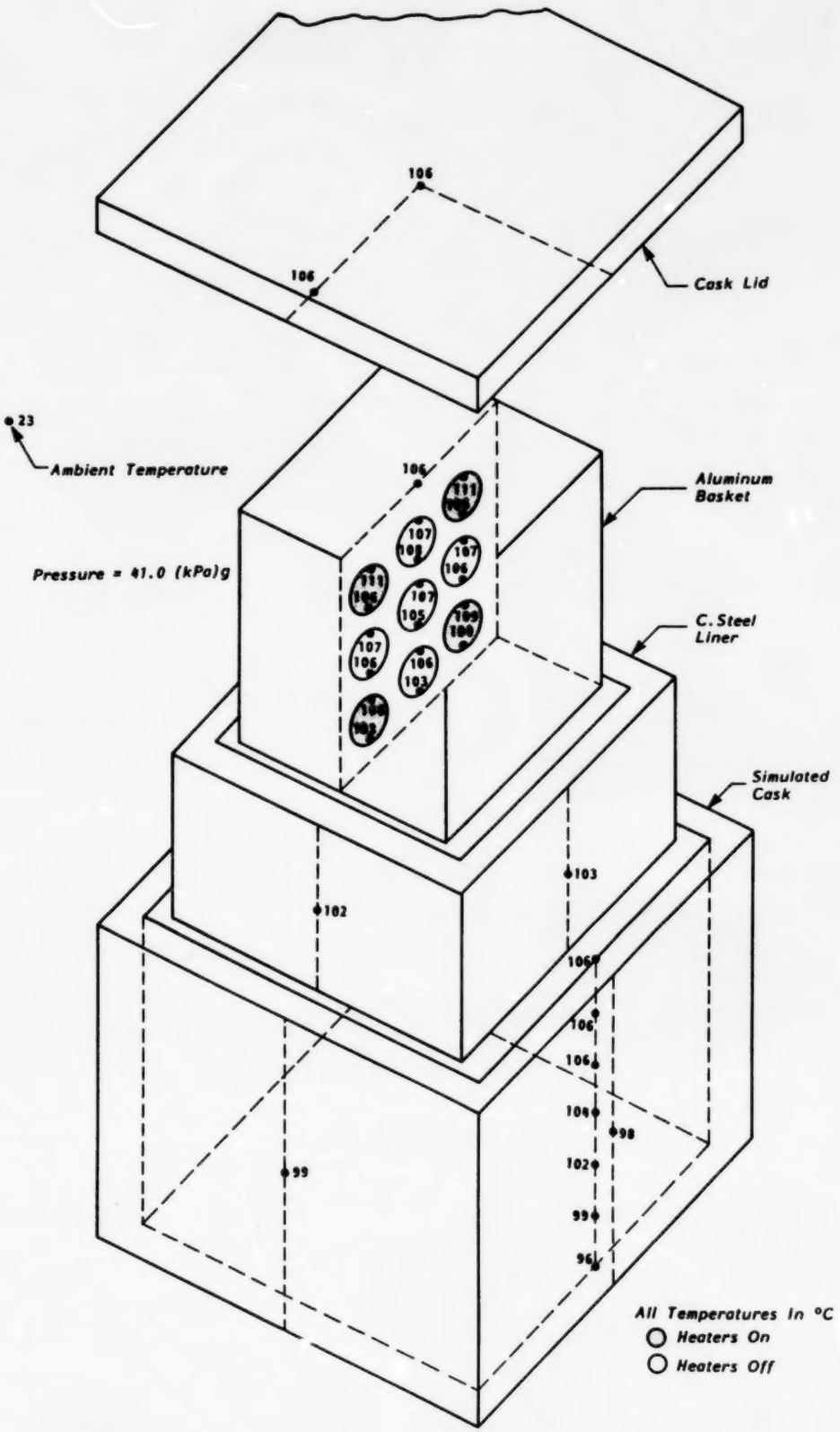


FIGURE 35

WATER CAVITY TEST WITH 8 BUNDLES AT 700 W/BUNDLE
AND WITH IMPACT LIMITER

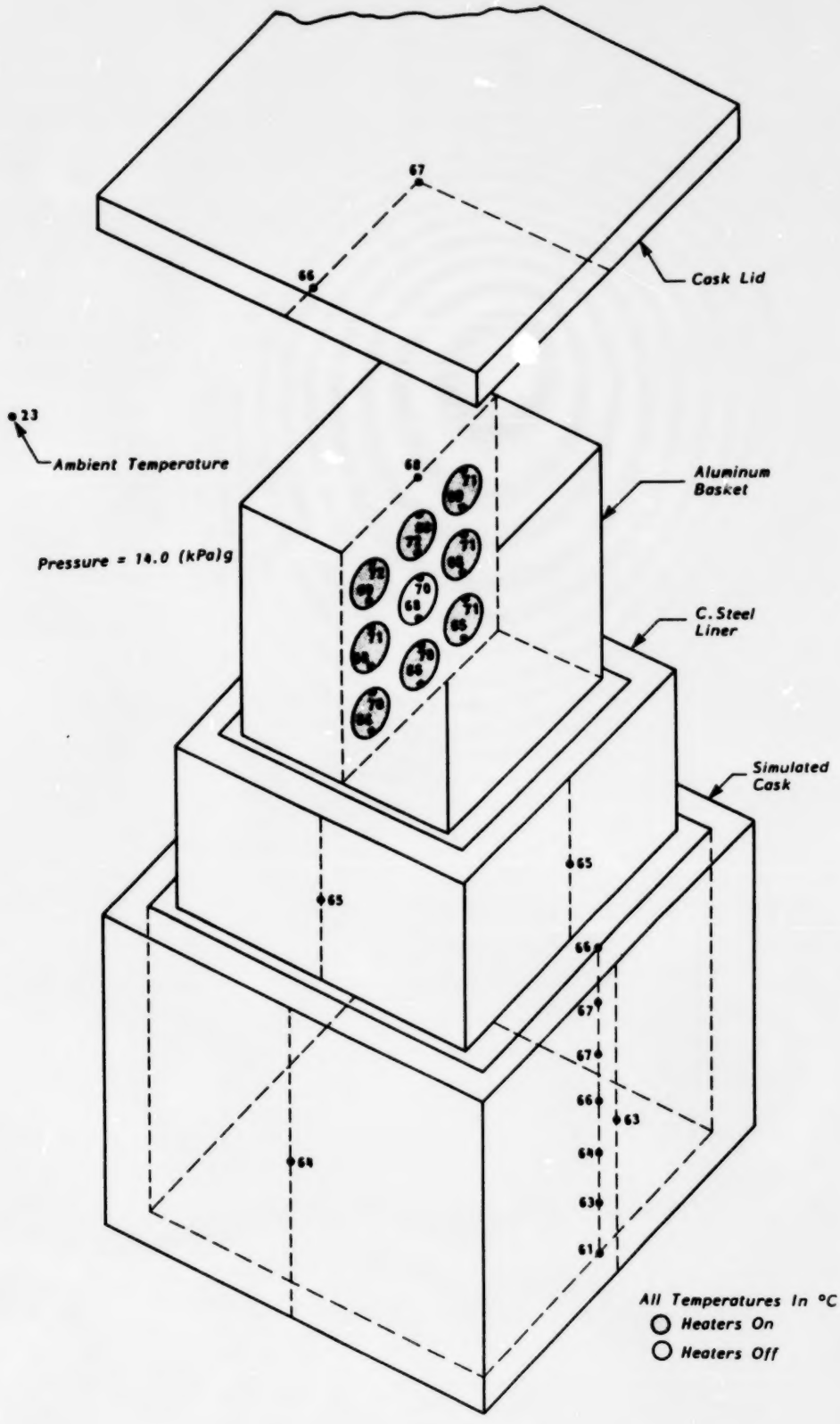


FIGURE 36

WATER CAVITY TEST WITH 16 BUNDLES AT 200 W/BUNDLE AND WITH IMPACT LIMITER

200845-RD

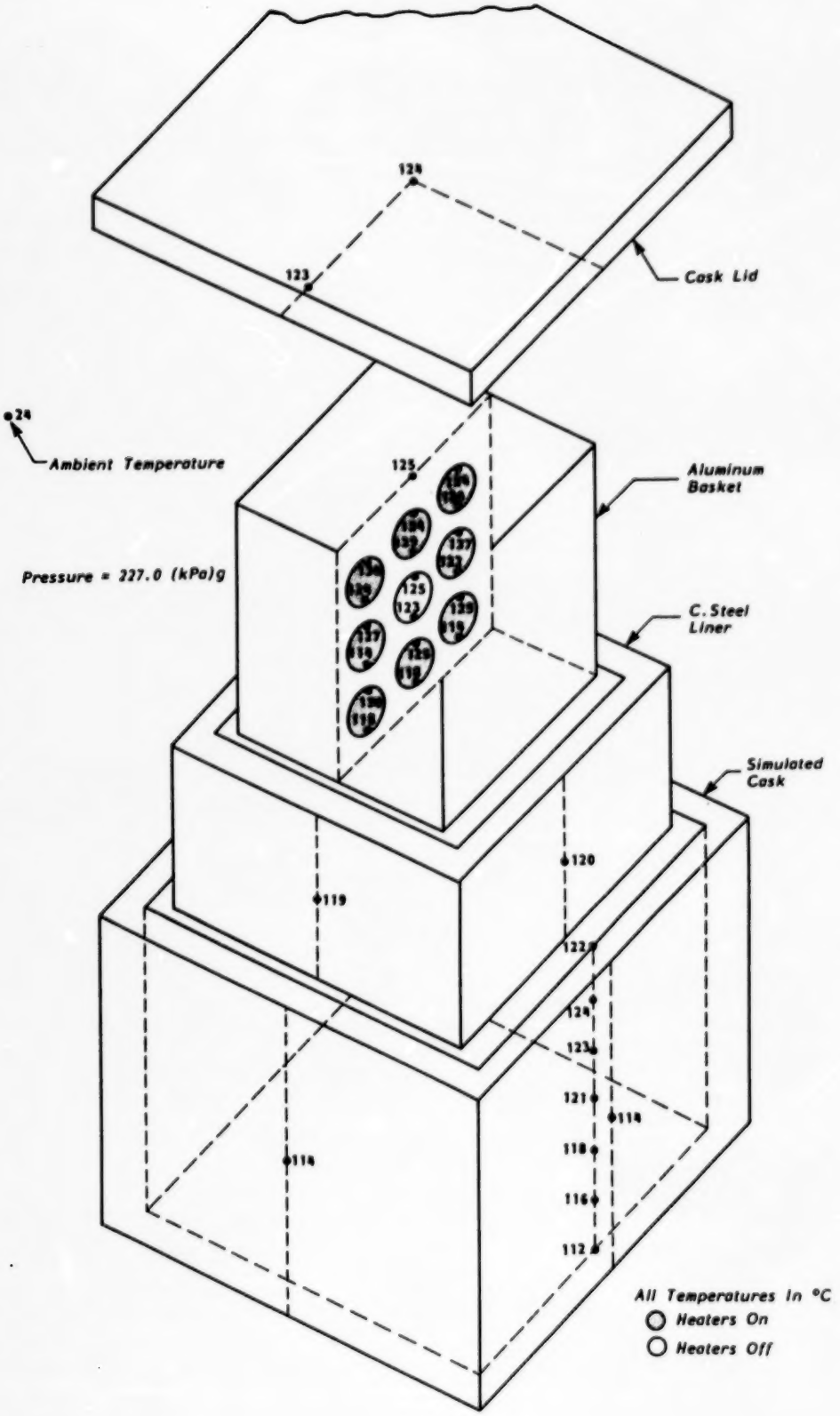


FIGURE 37

WATER CAVITY TEST WITH 16 BUNDLES AT 500 W/BUNDLE AND WITH IMPACT LIMITER

200846-RD

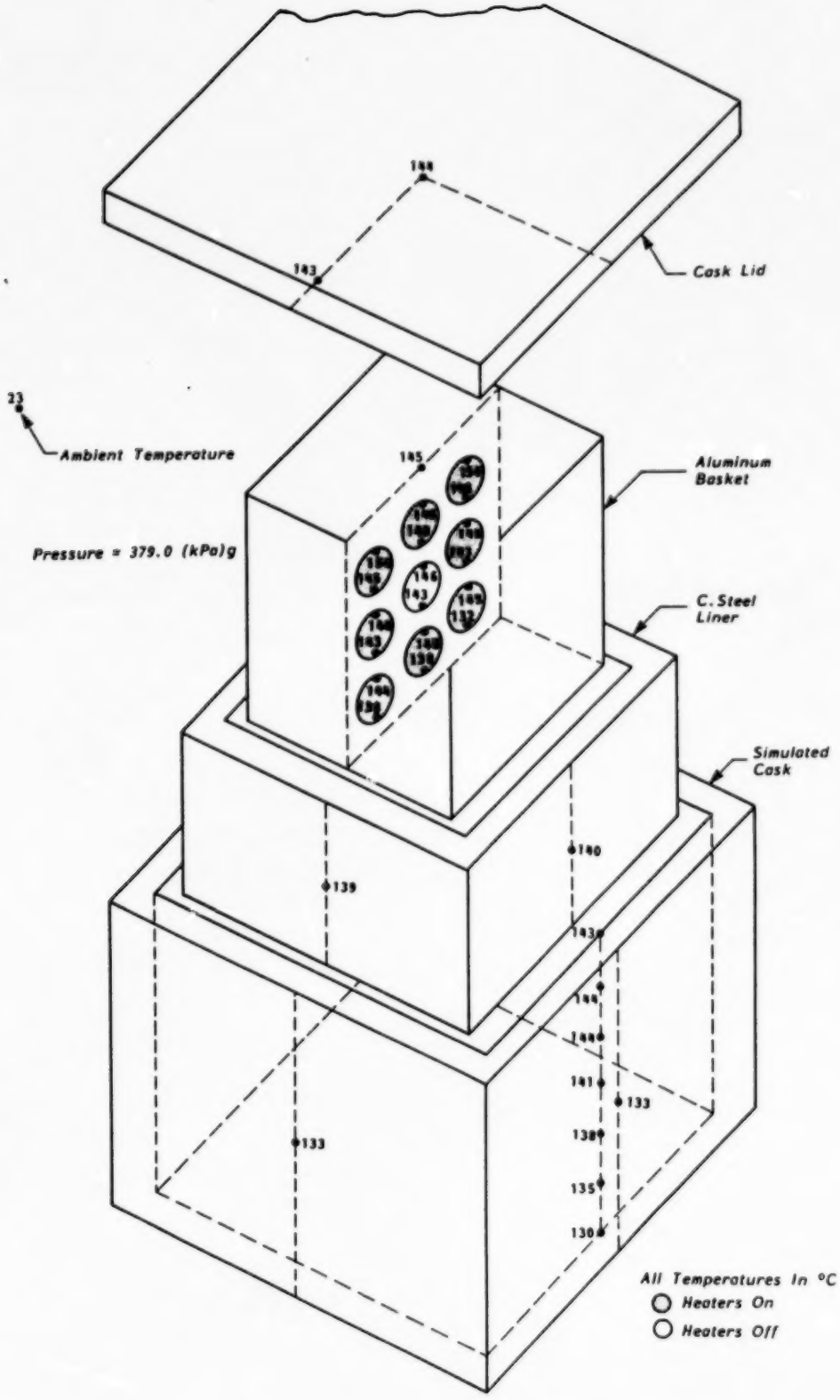


FIGURE 38

WATER CAVITY TEST WITH 16 BUNDLES AT 700 W/BUNDLE AND WITH IMPACT LIMITER

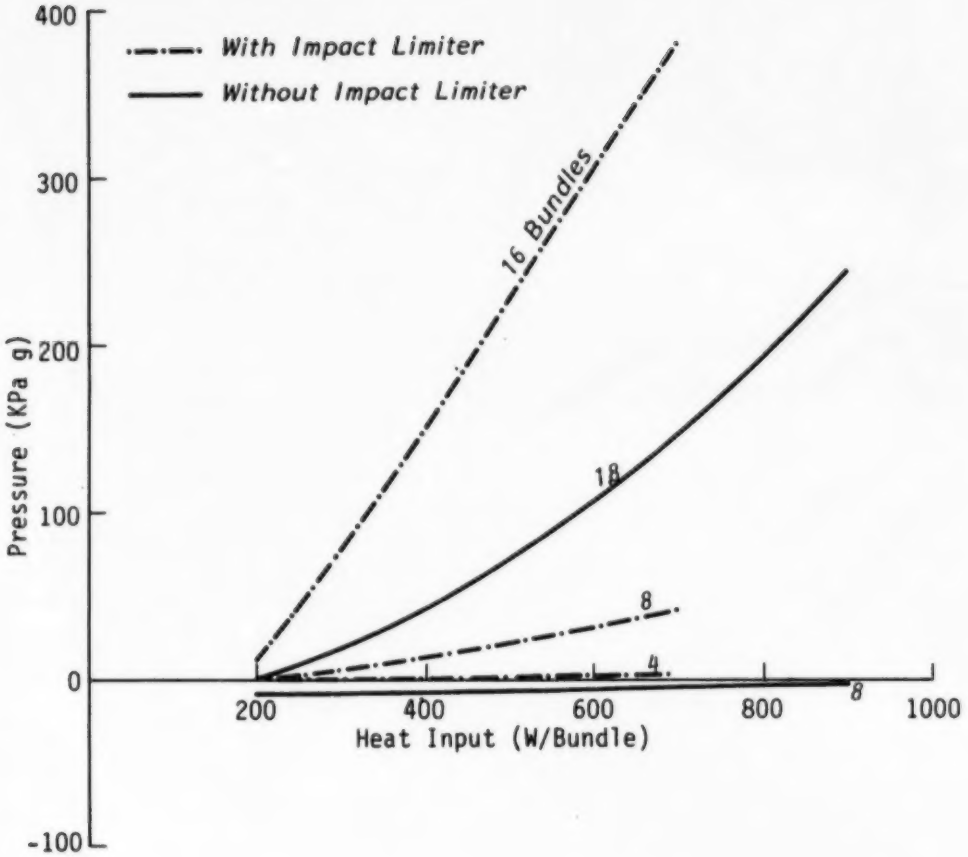


FIGURE 39
CAVITY PRESSURE FOR WATER CAVITY TESTS

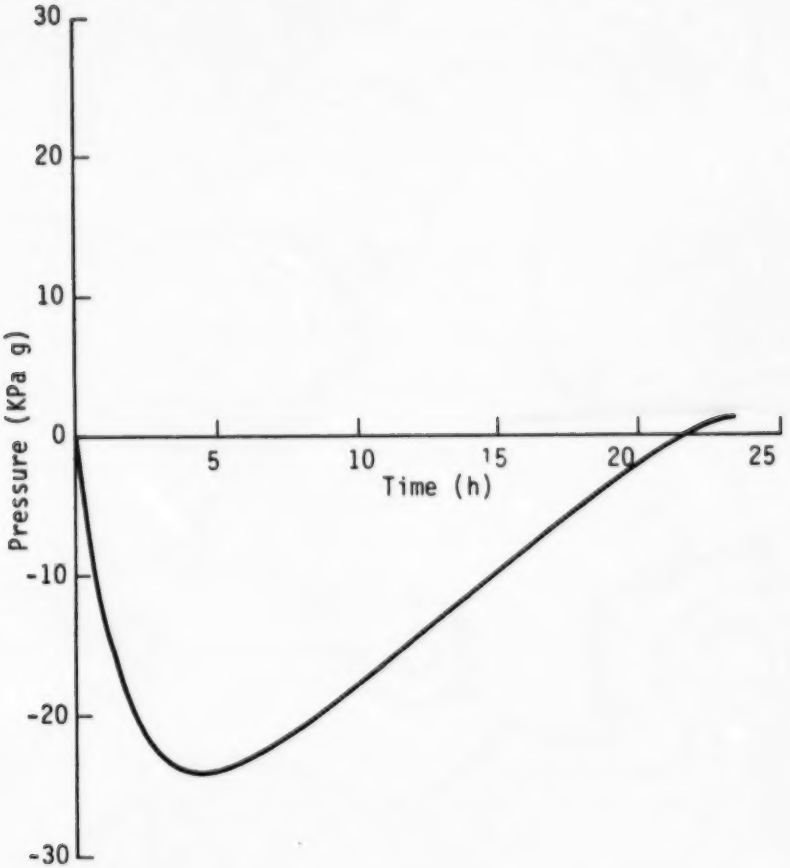


FIGURE 40
CAVITY PRESSURE DURING DRY UNLOADING TEST

175096-RD

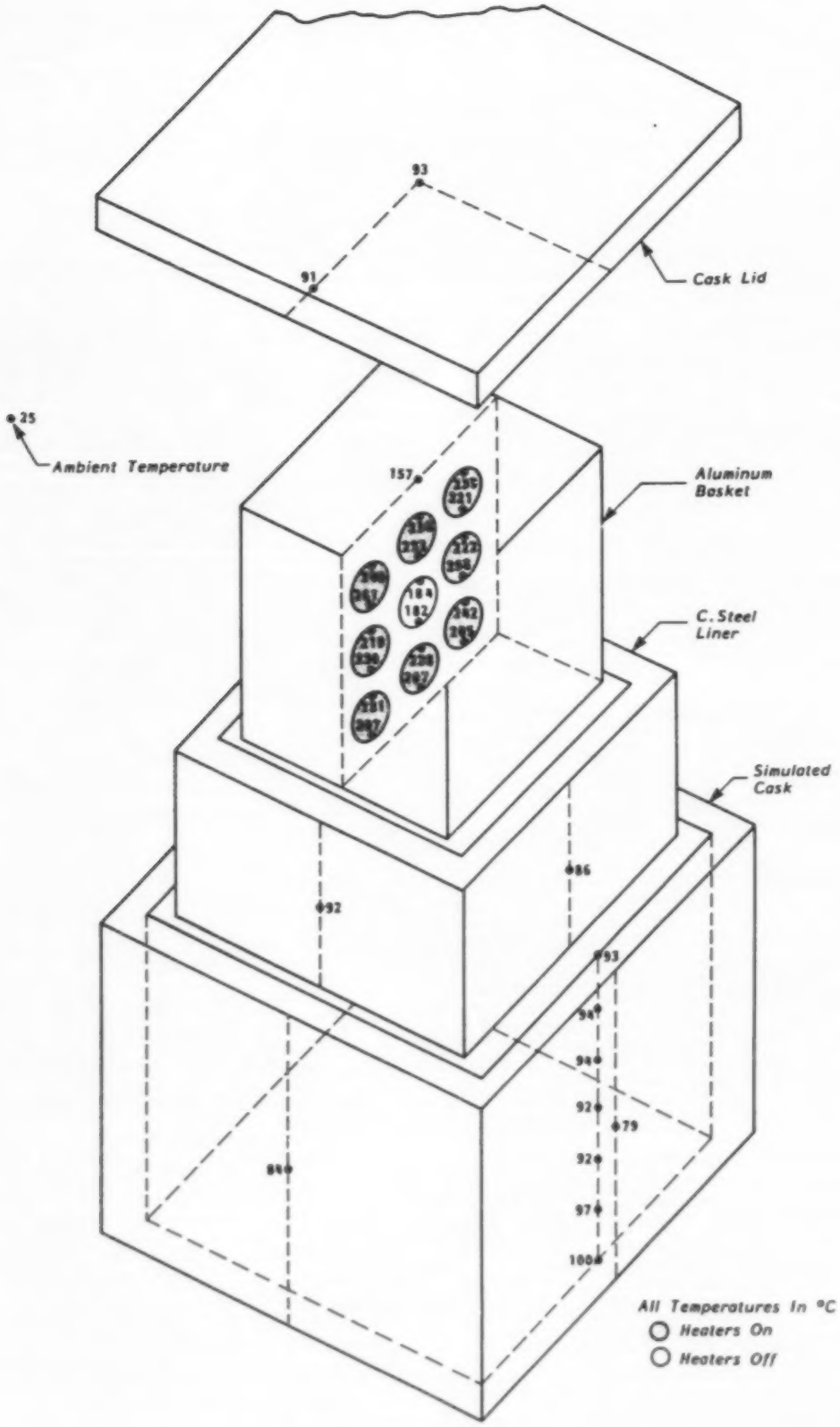


FIGURE 41

DRY UNLOADING TEST WITH 18 BUNDLES AT 550 W/BUNDLE
(CAVITY DRAINED)

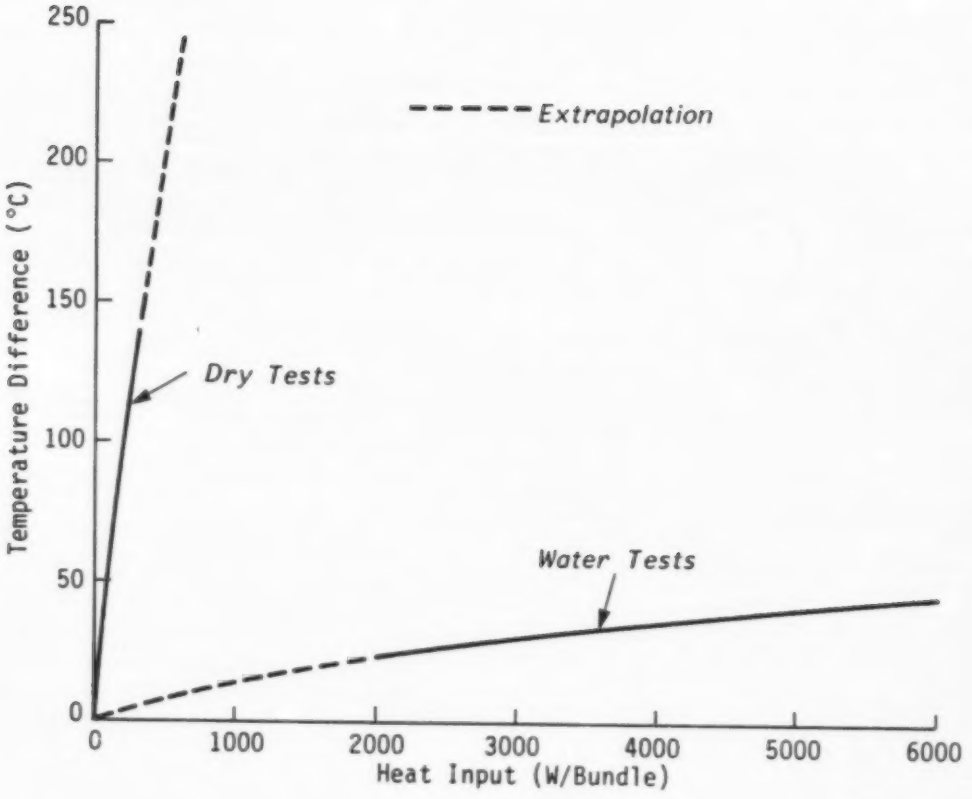


FIGURE 42

TEMPERATURE DIFFERENCE BETWEEN MAXIMUM FUEL SHEATH TEMPERATURE AND AVERAGE MODULE TUBE TEMPERATURE. GRAPH OBTAINED FROM REFERENCE/1/

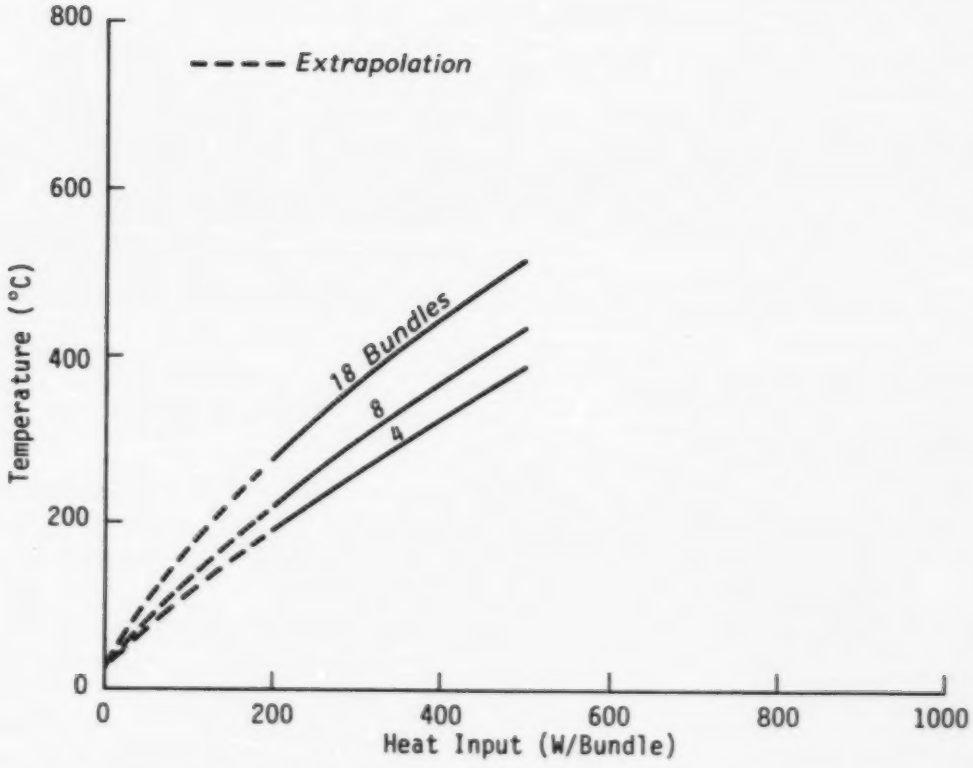


FIGURE 43

MAXIMUM FUEL SHEATH TEMPERATURE AS A FUNCTION OF BUNDLE HEAT INPUT FOR DRY CAVITY TESTS

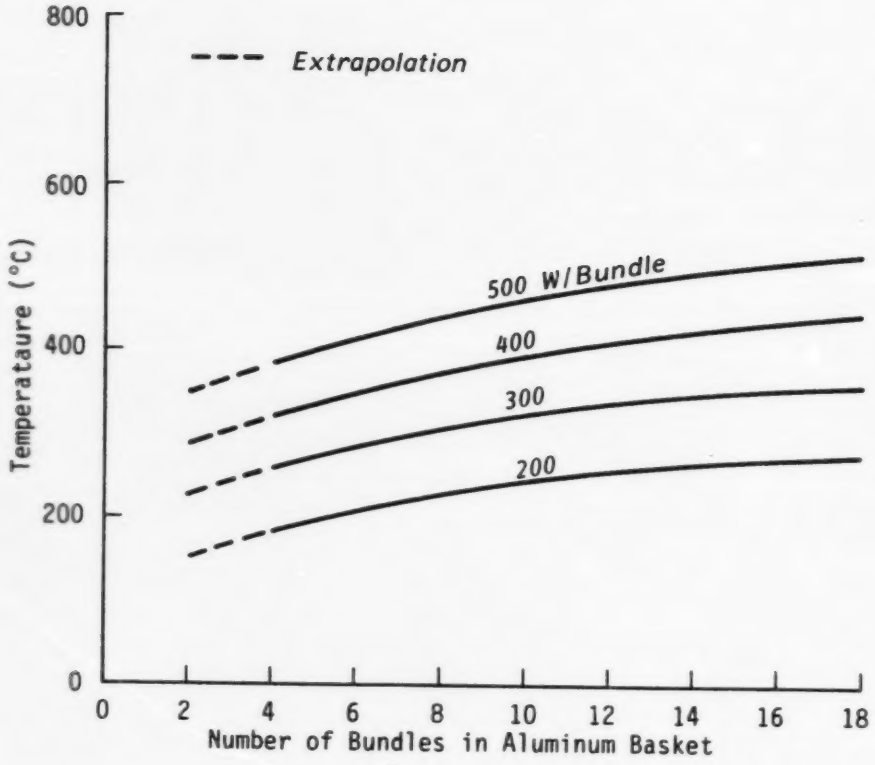


FIGURE 44

MAXIMUM FUEL SHEATH TEMPERATAURE AS A FUNCTION OF NUMBER OF BUNDLES FOR DRY CAVITY TESTS

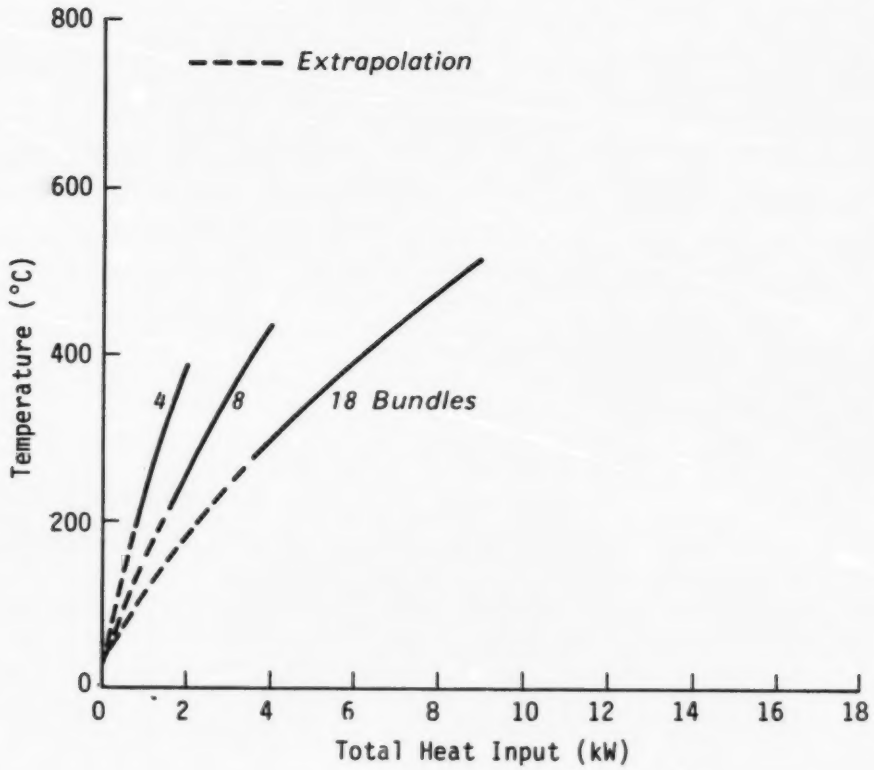


FIGURE 45

MAXIMUM FUEL SHEATH TEMPERATURE AS A FUNCTION OF TOTAL HEAT INPUT FOR DRY CAVITY TESTS

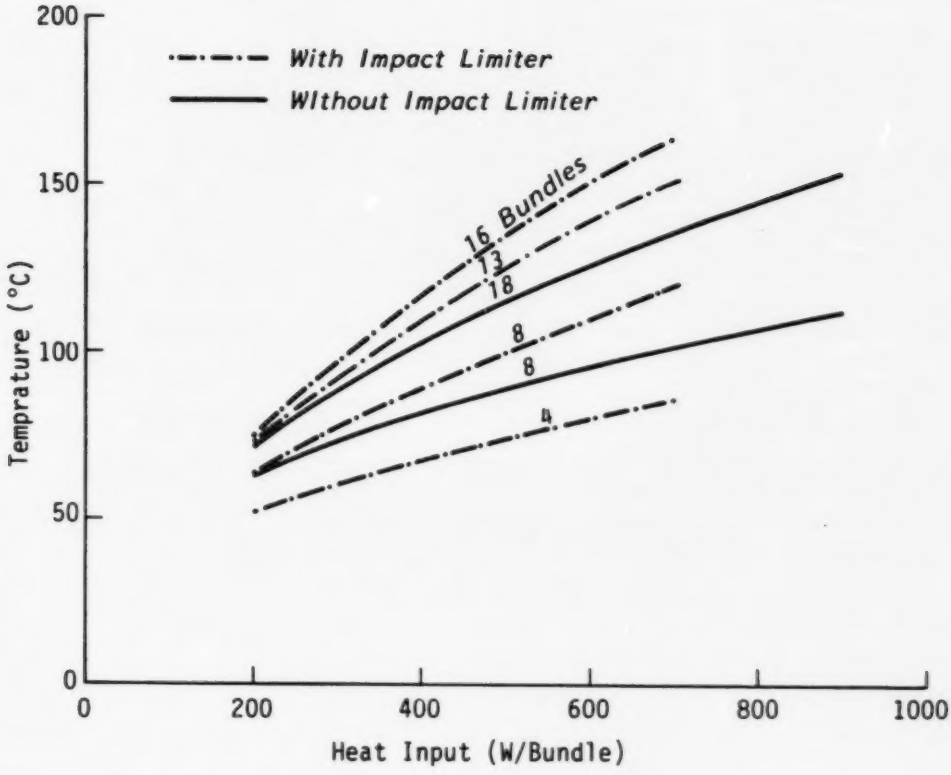


FIGURE 46

MAXIMUM FUEL SHEATH TEMPERATURE AS A FUNCTION OF BUNDLE HEAT INPUT FOR WATER CAVITY TESTS

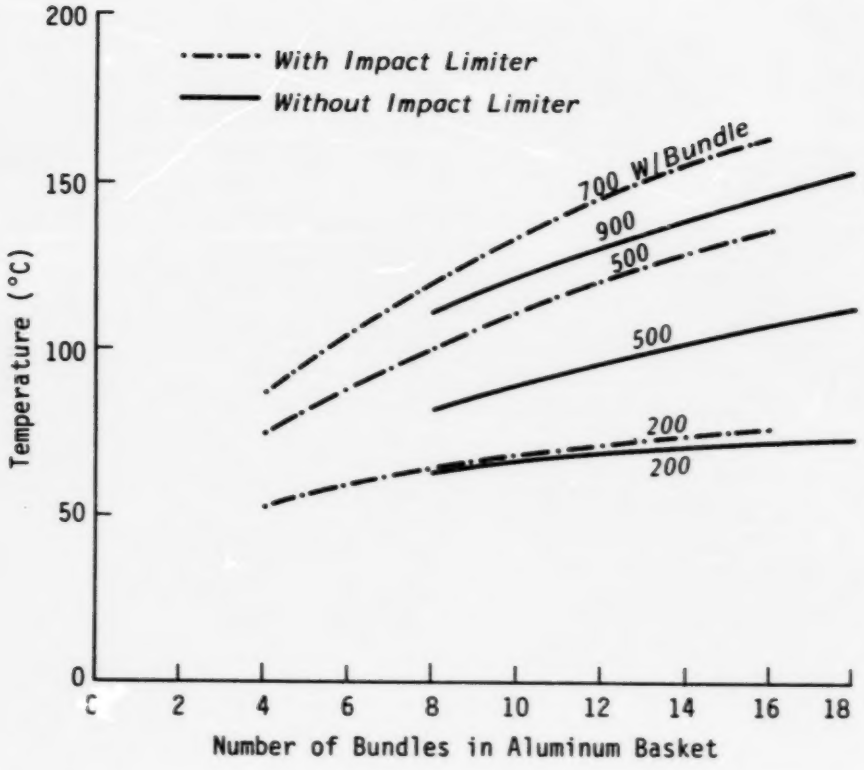


FIGURE 47

MAXIMUM FUEL SHEATH TEMPERATURE AS A FUNCTION OF NUMBER OF BUNDLES FOR WATER CAVITY TESTS

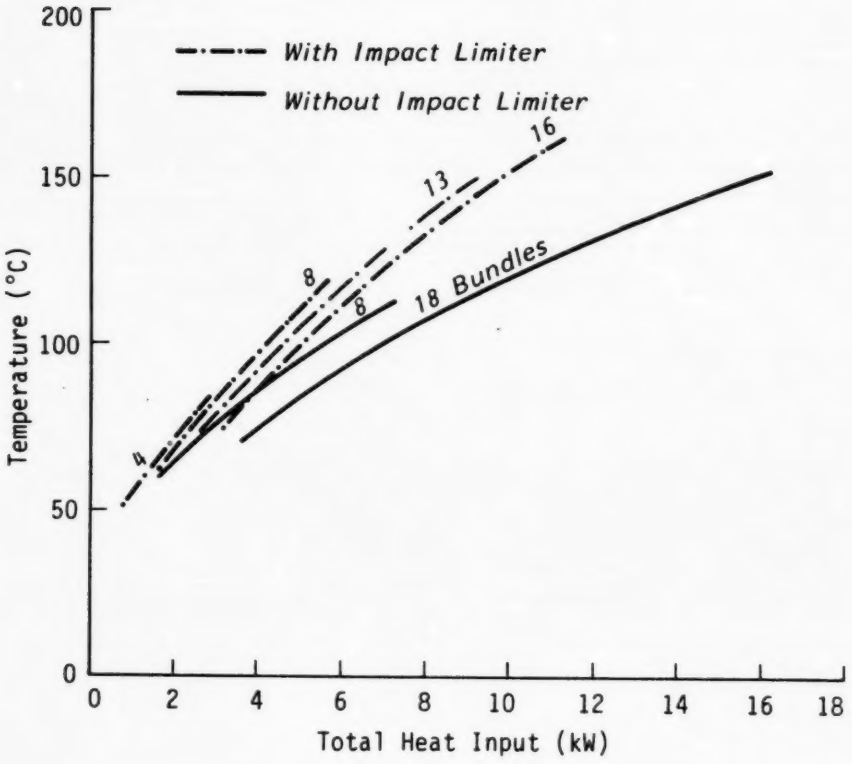


FIGURE 48

MAXIMUM FUEL SHEATH TEMPERATURE AS A FUNCTION OF TOTAL HEAT INPUT FOR WATER CAVITY TESTS

TABLE 1

LIST OF TEST CASES CONDUCTED

Test Description		Number and Arrangement of Bundles in Aluminum Basket (Each Configuration Tested at 3 Power Levels)			
		4	8	16	18
Dry Cavity Tests		● ○ ● ○ ○ ○ ○ ○ ○	● ○ ● | ○ ● ○ ○ ○ ○ | ● ○ ● ● ○ ● | ○ ● ○		● ● ● ● ● ● ● ● ●
*Water Cavity Tests	Without I.L.		● ○ ● ○ ○ ○ ● ○ ●		● ● ● ● ● ● ● ● ●
	With I.L.	● ● ● ○ ○ ○ ○ ○ ○	● ○ ● ○ ○ ○ ● ○ ●	● ● ● ● ○ ● ● ● ●	
Dry Unloading Test				● ● ● ● ○ ● ● ● ●	

I.L. = Impact Limiter

● Heaters On

○ Heaters Off

* Water Level at Top of Aluminum Basket

175104-RD

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